Systems Analysis Department annual progress report 1991

Larsen, Hans Hvidtfeldt; Petersen, K.E.

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Systems Analysis Department Annual Progress Report 1991

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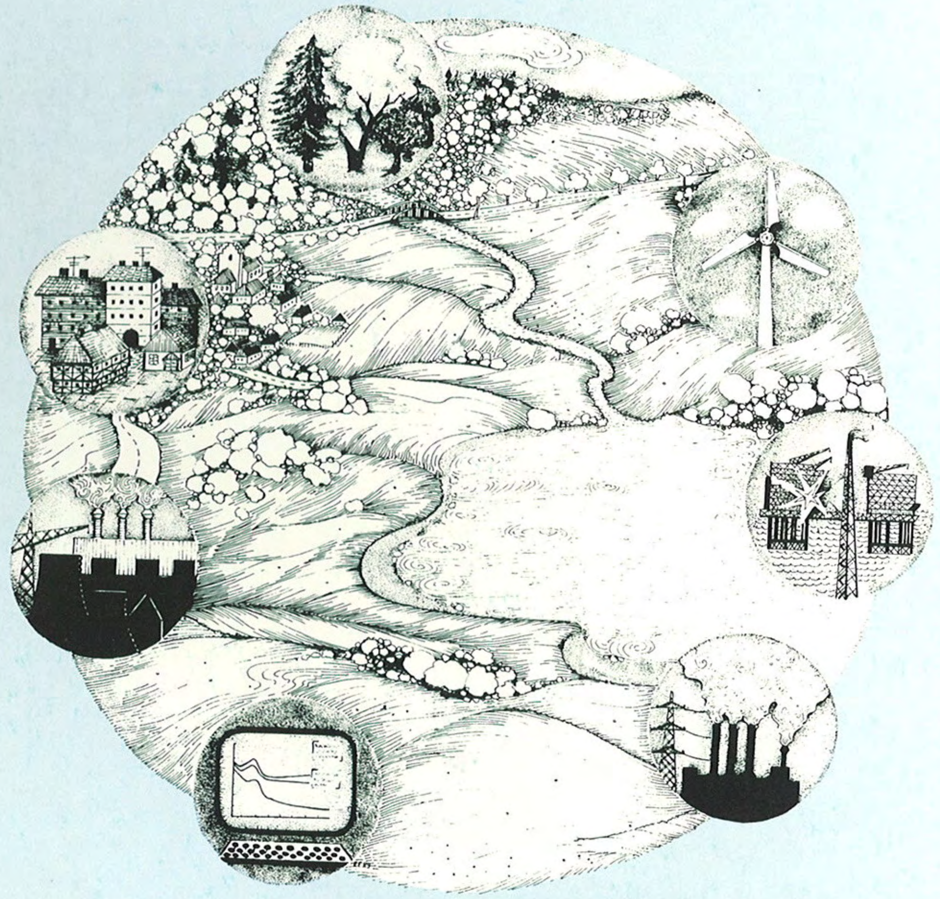

Risø National Laboratory, Roskilde, Denmark
March 1992

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Abstract The report describes the work of the Systems Analysis Department at Risø National Laboratory during 1991. The Department is made up of the Cognitive Systems Group, the Risk Analysis Group, the Energy Systems Group and the UNEP Collaborating Centre for Energy and Environment. The report includes lists of publications, lectures and staff members.

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Contents

1 Introduction

The Systems Analysis Department is engaged in R&D concerning methods and models dealing with the interplay among various technologies, systems and humans.

Following the major organisational changes at Risø in 1990, including the establishment of the new Cognitive Systems Group, and the creation of the UNEP Collaborating Centre on Energy and Environment, 1991 has been a year of consolidation, both with regard to research and staff. The research and development activities of the department include risk analysis, cognitive informatics, energy systems analysis and planning. The work is undertaken by the four groups: Risk Analysis Group (RAG), Cognitive Systems Group (COG), Energy Systems Group (ESG), and UNEP Collaborating Centre (UCC).

The department is multidisciplinary, and the permanent staff numbers 37 engineers, natural scientists, economists as well as social and behavioural scientists, together with 5 Ph.D. students and 8 supporting staff.

To a great extent the work of the department involves a close collaboration with Danish and foreign universities, research institutes, and industrial companies, as well as national ministries and international organisations such as the Commission of the European Communities, the Nordic Council of Ministers, IEA, UN/UNEP and IIASA.

The activities of the department in 1991 were financed 35% by government appropriations and 65% by funds derived from national and international research contracts and contract work. This is a strong shift towards contract funding, as the corresponding figures for 1990 were 50% each.

During 1991 two staff members have obtained the Ph.D degree from the University of Copenha gen, and two new Ph.D. projects have been initiated.

The Risk Analysis Group conducts research concerning reliability, consequence modelling, and risk management. In 1991 new research projects funded by the CEC STEP programme, have been initiated dealing with knowledge-based methodology for hazard identification, combustion of chemical substances, and flame experiments. Work has continued on the ENTOREL project, which was initiated in 1990 as a part of the CEC Teleman programme, with the aim to develop robots to work in disordered nuclear environments.

In 1991 the group has continued work on a joint European project together with VTT, Finland, JRC-Ispra and others to develop an integrated set of advanced software tools for safety and reliability analyses (STARS), using a knowledge-based approach and advanced information processing. The project is expected to be completed, with an operational prototype, early in 1992.

Finally, a number of concrete risk or reliability analyses have carried out, e.g a project for the Danish State Railway dealing with analysis of the reliability of the technical installations in the Great Belt Link between Zealand and Funen.

The Cognitive Systems Group is engaged in interdisciplinary research on user-centred information systems. In 1991 the most important event was the creation of the Centre for Cognitive Informatics, established jointly with the Centre for Cognitive Science at Roskilde University. The objective of the Centre for Cognitive Informatics is to coordinate the research activities within cognitive science and engineering, promote collaborative international links, and disseminate information.

In 1991 work was continued on the CEC ESPRIT II basic research project, Modelling of Human Actions in Work Context (MOHAWC). The project is carried out in collaboration with a number of European universities with Risø as main contractor; it will be completed in 1992.

In 1991 work was also continued on the CEC ESPRIT project IT support for Emergency Management (ISEM), carried out in collaboration with VTT in Finland, Kommunekemi in Denmark, and a number of European companies, again with Risø as main contractor. This project will also be completed in 1992. In 1991 the group has participated in European consortia formulating new projects to follow the above-mentioned projects to be completed in 1992.

The Energy Systems Group is engaged in research concerning methods and models to be used in energy and environmental planning and assessment of energy and environmental technologies. In 1991 the work concerning methods and new advanced models have involved a continued participation in the energy and environment modelling programme of the Commission of the

European Communities, i.e. the macro-economic model HERMES, and the Energy Flow Optimization Model (EFOM). The development of a forecast model for electricity demand in the service sector was started, and the project dealing with treatment of uncertainties in relation to integrated models was continued. A new major project dealing with hydrogen as an energy carrier was initiated in 1991. Energy planning activities in Eastern Europe was continued, and in 1991 with focus on the countries around the Baltic Sea, i.e. Estonia, Latvia, Lithuania and Poland. Assessments of new and renewable technologies have been undertaken; these included privately owned windturbines and joint biogas plants. Projects has since many years been carried out within the framework of the Nordic Council of Ministers; in 1991 this has included a project on electricity production versus electricity savings, and one on the consequences of the EC internal market for the Nordic countries.

The energy planning activities dealing with developing countries, have in 1991 focused on the Cape Verde Islands.

The UNEP Collaborating Centre on Energy and Environment was established with the aim of promoting the incorporation of environmental considerations into energy planning and policy worldwide, particularly in developing countries. The Centre is financed jointly by the United Nations Environment Programme (UNEP), the Danish International Development Agency (Danida) and Risø.

The centre was officially inaugurated on 11 February 1991, and during the year the centre has become fully operational and staffed with a team of five full-time international experts. A central activity of the Centre in 1991 has been work on the Environmental Database in collaboration with the Stockholm Environment Institute's Boston Centre. Collaborative activities have been started in 1991 with a number of organisations in Latin America dealing with databases and planning tools.

By the end of 1991 a major new project was launched aimed at establishing a set of methodological guidelines for calculating the costs of limiting greenhouse gas emissions, in particular carbon dioxide from the energy sector. The Energy Systems Group is acting as the Danish participant in this project.

Finally, during 1991 the Centre published the first two issues of the newsletter C2E2 News, containing information on Centre activities and related topics.

In 1991 the department was heavily involved in organising an international conference on Environment, Energy, and Natural Resource Management in the Baltic Region , which took place 7 - 10 May 1991 in Eigtveds Pakhus in Copenhagen. It attracted 115 participants representing all countries around the Baltic Sea.

2 Risk Analysis Group

The research carried out by the Risk Analysis Group is directed towards reliability of complex systems, consequence modelling, and risk management. In 1991 the work concentrated on launching four major research projects funded by CEC programmes.

The group has become the coordinator for a CEC TELEMAN project aiming at development of a tele-operated robot able to work in hazardous nuclear environments. The work in 1991 comprised the establishment of a reliability model of the robot, to be extended and refined throughout the design process.

It is recognized that human and organisational aspects play an important role in accidents. This requires developing methods which integrate systematically technical, human and organisational aspects. This work was initiated in 1991 in a project under the CEC STEP programme.

In order to assess the consequences of accidents at industrial plants, experiments are required to give a better understanding of the chemical or physical phenomena and to verify methods and models. Two areas were selected: flame characterization and combustion products analyses. The first focused on the consequences of a fire with flames impinging on a vessel containing pressurized liquid. The latter concentrated on a characterization of the combustion products generated by a fire in a storage of chemicals.

Two initiatives taken previously were continued in 1991. The development of a prototype of STARS, which is intended for reliability and safety analysis, centred on implementation of three knowledge bases. The effort on reliability-based maintenance planning was directed towards the use of condition monitoring data in a Nordic research project.

Finally, a number of specific reliability or risk analyses was carried out of which the most important one was a project for the Danish State Railways. The aim was to assess the reliability of the technical installations in the Great Belt link tunnels to avoid train traffic interruptions or disturbances.

2.1 STARS: Software Tool for Analysis of Reliability and Safety

STARS is an integrated set of software tools which is able to assist analysts and designers in the various phases of plant safety and reliability analysis. The target application areas are the process plant industry, the nuclear industry and other industrial sectors where complex electromechanical systems are used.

STARS is bringing the domains of artificial intelligence and advanced information processing into the field of safety and reliability analysis in a more application-oriented way than earlier systems.

The STARS project is a collaborative effort of four partners, Risø National Laboratory, the JRC-Ispra, the Technical Research Centre of Finland and the Italian Company TECSA. During the three-year period the project has attracted several important affiliate members. By the end of 1991 the project work is so far advanced that a completion in 1992 fulfilling all major goals can be foreseen.

A qualitative analysis module is available to the analyst. This module contains three chemical expert systems and a plant/unit expert system which supports the interactive modelling of hazardous events and event sequences. The qualitative analysis package also offers the possibility of investigations based on guideword lists for a systematic search for potential problems and check lists of potential hazards.

Analyses on selected problems can be performed with the fault tree modules which take their data from knowledge bases for piping and instrumentation and for components. Consequence and vulnerability assessment modules are also available.

A functional block diagram for the complete STARS package is shown in Figure 2.1.

The main responsibility of Risø has been to develop the chemical expert systems. They consist of three expert system shells and three knowledge bases. The shells have been completed in 1991 and some knowledge has been supplied as well. All three knowledge bases contain two types of knowledge, i.e. generic knowledge supplied by the STARS development team and specific knowledge to be supplied by analysts for their own plants.

All knowledge is stored in the object-oriented Frame Management System especially developed

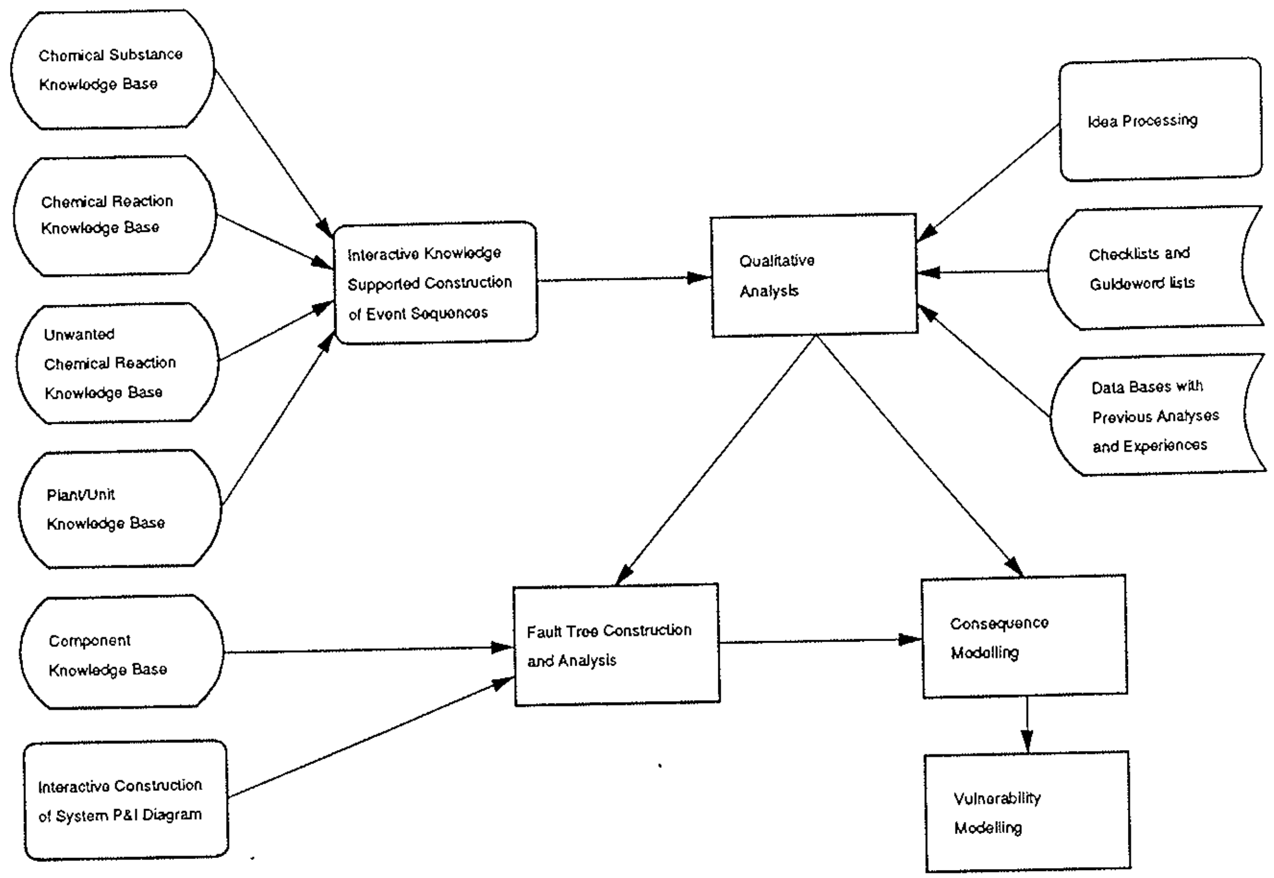


Figure 2.1. The modules in STARS.

for STARS. Each item is kept in a frame and the attribute values are stored in slots. Each entity is described by remarks, descriptions, and rules of the type »IF high temperature THEN fire«. The expert systems do reasoning on the rule sets according to the problems raised.

The chemical substance knowledge base contains a database with physical, chemical and toxicological properties of the substances and their potential hazards are given in rule form. The chemical reactions knowledge base contains general descriptions of the reaction classes as well as rules detailing their potential hazards. Both knowledge bases are interrogated for so-called generic hazards like »fire« and »explosion«. The knowledge base for unwanted chemical reactions contains a reaction matrix in rule form and a set of rules valid for the simultaneous appearance of three or more specific substances. The expert system checks all possible combinations of substance classes and/or substances; afterwards, the analyst will have to check if any of these combinations can appear with relevant amounts of chemicals so as to constitute a hazard.

The three expert systems can be called from other program modules of STARS, but also have their own X-window user interface for off-line use. All program modules are available for SUN SPARC-stations.

Publications in 1991: 10, 11 and 78.

2.2 ENTOREL

The Commission of the European Communities has initiated a programme called TELEMAN with the objective of developing advanced teleoperators (robots) that can operate in hazardous or disordered nuclear environments. In the present first phase, the programme consists of 16 projects, each covering a part of the development of components and subsystems - »building blocks« in the TELEMAN terminology.

The Risk Analysis Group acts as coordinator of the project TM41, ENTOREL (ENvironmental TOlerance, RELiability and safety) which began by the end of 1990. This project has a »cross disciplinary« role in the sense that its subjects are relevant to all the other projects. The

other partners in ENTOREL are AEA Technology's Harwell Laboratory (UK), CEN/SCK (Belgium) and Siemens Energieerzeugung KWU (former Interatom) (Germany).

The function and reliability of a »TELEMAN machine« will be affected by environmental factors such as dust, water vibrations, heat, and ionizing radiation. In particular, knowledge is missing about the effects of large doses of ionizing radiation (106Gy) which are relevant here. Furthermore, knowledge at system level, i.e. of the behaviour of the whole robot when subjected to a hostile environment, is lacking.

The programme has not yet selected one specific type of robot for analysis, but three types of conceptual machines are being considered: 1) mobile machine, 2) gantry-type manipulator and 3) long reach device, either an articulated long-reach arm or a »pipe crawler«. Whatever type will be selected, many of the problems relevant to ENTOREL will be the same, although the types of task and environment may differ.

Any TELEMAN machine will be exposed to environmental conditions which may cause loss of performance or even failure earlier than would otherwise be the case. Work is being carried out under the ENTOREL project to enable these environmental factors to be taken into account in order to prolong the lifetime of the system, at least until more usual failure mechanisms (for example, failure of mechanical components due to wear) become dominant. Environmental andoperational demands to be met by the machine include:

- radiation tolerance: 10^6Gy at 10 Gy/hr (at most exposed parts)
- humidity: up to 100%
- service intervals:2000 hours operational time
- resistant to fumes and splashes of HNO_3 and other decontamination fluids of task and environment may differ.

Relevant components and materials which are considered especially susceptible to radiation damage are: electronics, sensors, fibre optics, signal communication systems, insulating materials, lubricants, and adhesives. As part of the project, radiation effects data for relevant equipment already on hand will be entered into a database. In addition, radiation testing of components and materials will be carried out to cover gaps in the existing data.

A task to run throughout the project will be the collection of data and other information from external (to TELEMAN) sources and the dissemination of this information as well as that generated by the project to the partners of the other TELEMAN projects. Contacts are established with external (to TELEMAN) bodies possessing data or other relevant information in order to set up agreements on collaboration. For example, collaboration has been established with the European Space Agency, ESA, concerning the transfer of data which ESA has produced for radiation effects on electronic components with a view to satellite applications.

Reliability models for the machine and its subsystems have been set up during 1991. The overall purpose of this work is to predict the time the robot will be able to operate in the radiation field before it has to be taken out for maintenance, and ascertain which parts of the machine are critical in this respect.

The detailed design of the robot is not determined at the start of the project. Therefore, the reliability analysis has started from a conceptual stage and will be refined as the design evolves. Figure 2.2 shows the coarse initial block diagram for the analysis.

The first steps of the reliability analysis have been the identification of tasks to be performed by the robot (e.g. »drilling« and »decontamination«), the breakdown of these tasks into sequences of ta sk steps, such as »acquire tool« or »deploy tool«, and the specification of systems and resources necessary to perform the task steps, e.g. »motors« and »power supply«.

Breaking down further into subsystems and components, a point will be reached where reliability data for the components are available or where further breakdown becomes meaningless. From this point fault trees can be set up with a view to making a quantitative evaluation of the system reliability.

The robots aimed at in the project will be more or less autonomous, meaning that they will be performing their tasks without continuous contact with an operator. In order to ensure that the robot returns to a safe state and location when faults occur failure strategies must be established, based on the reliability models developed.

Publication in 1991: 34.

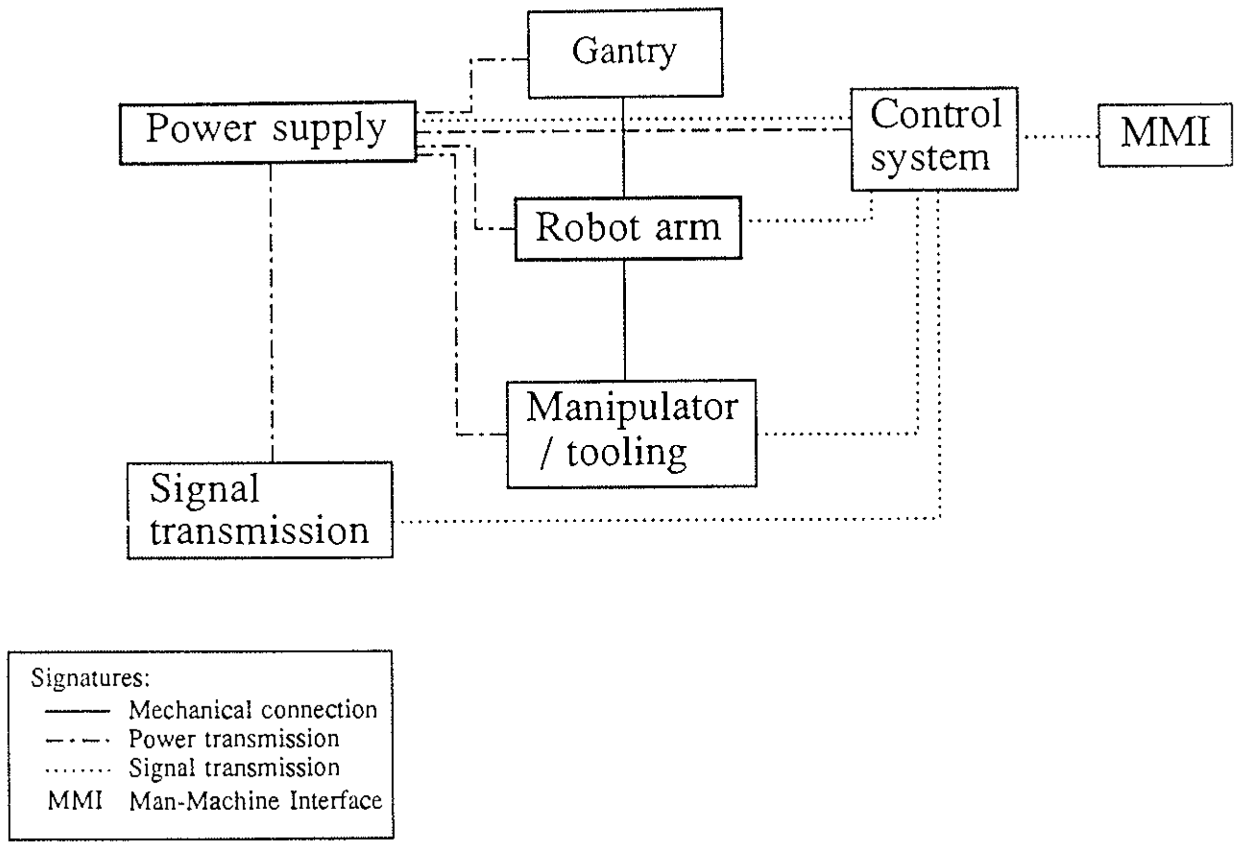


Figure 2.2. TELEMAN machine block diagram for initial reliability analysis.

2.3 An Overall Knowledge-Based Methodology for Hazard Identification at Plant Level - TOMHID

The objective of the project is to develop an overall knowledge-based methodology which will provide assistance and güidance to the user for hazard identification purposes and which follows the development of an incident in every stage of the event chain. Parts of the methodology will be based on computer-based hazard identification. Where appropriate the program will utilize knowledge-based techniques as the basic programming approach. Much effort will focus on providing a user-friendly environment which is suitable for group sessions. The output of report material from the system will also be a key factor.

The basic feature of the methodology will be to develop a concept for describing a process plant as a socio-technical system which is useable for hazard identification at plant level. The high-level screening tool shall cope with technical, human and organisational aspects and is intended to be used as a first stage in the hazard identification process. This will identify areas with a need for further analysis using well-established aproaches.

The project is funded by the CEC STEP-programme. It has been initiated in 1991 with a duration of three years. The project is carried out by an international consortium including the following partners: The Technical Research Centre of Finland, Risø National Laboratory, The University of Sheffield, The Safety and Reliability Directorate, CIEMAT, Joint Research Centre and Tecsa.

In 1991 a review has been carried out of existing hazard identification methods, risk-ranking methods and computer tools describing their benefits and limitations. A questionnaire has been developed and distributed to chemical industries and authorities in United Kingdom, Spain, Finland and Denmark with the objective of clarifying the potential user needs for plant level hazard identification methodologies. The results from this exercise (which will be available primo 1992) and the recommendations from the review of existing met hods will form a basis for the next phases of the project.

In the next phases of the project the contributions from Risø will concentrate on the conceptual study on development of the socio-technical plant description and specifications for a knowledge-based high-level hazard identification tool. Finally, Risø is to be responsible for the last part of the project which comprises planning of test experiments and evaluating the developed knowledge-based hazard identification tools.

2.4 Maintenance Planning Using Reliability Analysis and Condition-Monitoring Indicators.

In the beginning of 1991 a project concerning condition monitoring indicators was initiated by Risø, Sydkraft and the maintenance department of the Swedish Nuclear Power Plant Barsebäck. The project was carried out under the Nordic Nuclear Safety programme NKS/SIK1, which deals with the two subjects LPS A (living probabilistic safety analysis) and safety indicators.

The aim of the project was to establish a system for maintenance planning using the results from the reliability analysis of failure data and the measured condition of the components.

The preheater system at the Barsebäck nuclear power plant was selected as a test system for a feasibility study, with the purpose of ascertaining if the necessary information in the form of process data and failure reports was available.

On the basis of the results from the feasibility study, the feedwater pump system was selected for a detailed study.

Historical information is extracted from failure reports to increase the knowledge of ageing of the components and to be able to predict when a repair or replacement of the components or their parts is necessary.

The analysis is based on reported events that occurred in the period from 1980 to 1990. Several trends concerning unavailability have been investigated based on a study of:

- number of failures versus time,
- accumulated failures versus time and
- repair time due to failures versus repair time due to maintenance.

Some statistical analysis methods to be used have been considered, in particular the proportional hazards method (PHM) has been compared to alternative ones.

Each component in a plant has specific working characteristics to which the actual behaviour of the component can be related. A deviation from the expected characteristic expresses a degradation rather than malfunction of the component. This type of condition monitoring was developed using data from existing process monitoring equipment at the plant.

A computer program has been developed which presents the condition monitoring data of the components in the preheater system. The displays show the working characteristics of the component and any deviation from the characteristics.

In the continuation of the project a stand-by system will be treated in a manner similar to that of the preheater system. Further, the development of a link between the information on failed or degraded components and systems unavailability will be considered to support the reliability-based maintenance planning.

Publications in 1991: 44,46,47 and 48.

2.5 Combustion of Chemical Substances

Fire involving a great amount of chemical substances is often identified to be an important risk from a chemical plant or storage facility. However, it is very difficult to assess the effect of such a fire on humans in the neighbourhood. To a great extent this is due to the very limited knowledge about combustion products from fires.

Therefore, a research project entitled »Combustion of Chemical Substances and the Impact on the Environment of the Fire Products« has been initiated in 1991 and will continue until 1994. The project is funded by the CEC STEP programme. The participants, apart from Risø National Laboratory, which acts as coordinator are South Bank Polytechnic (UK), VTT (Finland), Lund University (Sweden) and Swedish National Testing and Research Institute (Sweden).

The objective of the project is to obtain data on the identification and quantification of fire products from fires in warehouses containing commercial chemicals. The project comprises experiments of various scale in order to identify the source term characteristics and the relation between bench-scale testing and real fires. The project contains an identification of the relevant fire scenarios, microscale, small-scale, model-scale and large-scale experiments, and also characterizations of the particles produced in the fire.

Risø will identify the fire scenarios in collaboration with VTT and carry out the microscale experiments.

In 1991 the Risk Analysis Group initiated the construction of a database covering chemical fires which have occurred in Europe during the last ten years. By use of the database it is possible to select the relevant fire scenarios for the experiments which are carried out. A preliminary list of substances which will be subjected to microscale experiments has already been constructed. The substances on the list are representative for the groups: chlorinated pesticides, organophosphorus pesticides, fertilizers, polymers, and chlorinated solvents.

In 1991 the group constructed a combustion furnace in accordance with the DIN 53 436, and the first microscale experiments have been carried out in collaboration with the Combustion Chemistry Group.

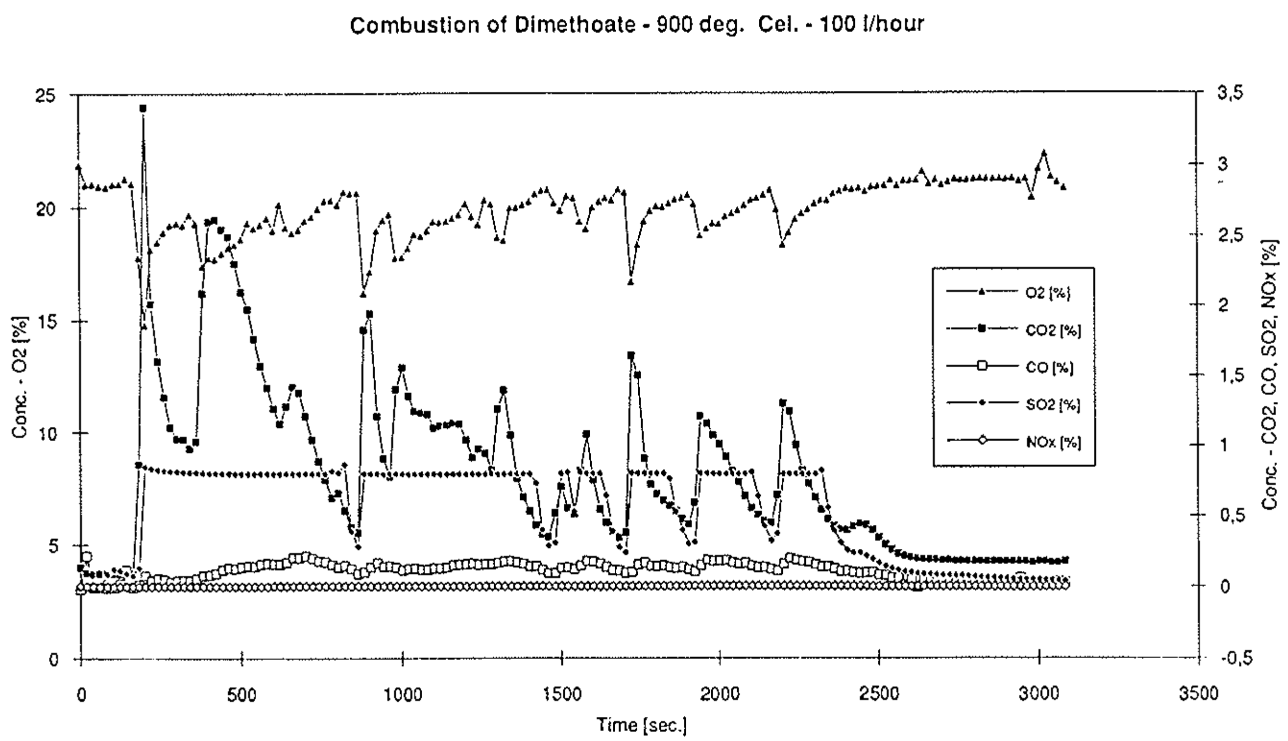
The furnace consists of a quartz combustion tube and a movable annular electric oven which encloses a section of the tube. The substance subjected to combustion is placed in a quartz boat inside the tube. The oven moves along the tube and air enters the tube in the direction opposite the movement of the oven. The mixture of air and combustion products are collected and analyzed.

In 1991 combustion experiments were made with the two substances lindane (chlorinated pesticide) and dimethoate (organophosphorus pesticide) and analyses of the combustion products carried out. The experiments took place at various furnace temperatures (500, 700, 900°C) and airflows (100, 300 liters/hour).

Concerning lindane, on-line measurements were made of the content of O_2, CO, and CO_2 in the combustion gas, the generated total amount of HCl was determined, and the generated total amount of organic combustion products was collected and analyzed by GC and GC/MS. In the future it is expected that the generated amount of COCl2 will be determined as well.

In the case of dimethoate, on-line measurements of the O_2, CO, CO_2, SO_2 and NO_x generation have been carried out (Figure 2.3). A determination and analysis of the generated total amount of inorganic combustion products also took place by converting the gases to salts and performing a n analysis by ion chromatography and titration. Finally, the generated total amount of organic combustion products was collec ted and analyzed.

Figure 2.3. An example of the on-line measurements of generated O_2, CO, CO_2 and NO_x from combustion of dimethoate.



The results of the microscale experiments will then be evaluated together with the results of the larger-scale experiments which are carried out by the other participants in the project by the end of the project period.

The Ph.D. study entitled »Toxic products in smoke from chemical fires«, which was initiated in 1990 will also comprise combustion experiments with the DIN 53 436 furnace. The chemical substances which will be subjected to combustion are chlorinated pesticides. Furthermore, toxicological inhalation experiments will be carried out with one of the chlorinated pesticides, i.e. animals will be exposed to the combustion products. In 1991 a literature survey has been performed in order to be able to design the experiments. Finally, toxicological inhalation methods have been studied during a six-month stay at ICI, Central Toxicology Laboratory (U.K.).

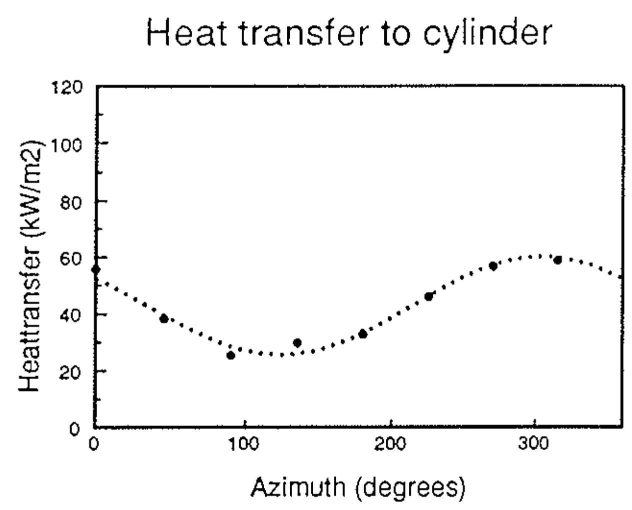


Figure 2.4. Heat transfer to a cylinder impinged by the jet flame. Data points are measured at eight positions around the middle of the cylinder.

2.6 Flame Experiments

The department operates an open-air jet-flame facility, where experiments can be performed with natural gas flames. Flames of a maximum power of 6 MW and lengths of about 10 meters can be achieved. The purpose of the experiments is to quantify the behaviour of such flames and the processes taking place within them, in order to improve the understanding of flames in general, and in particular, to quantify risks involved in the handling of flammable gases.

Throughout the period 1988-1991 SYS participated in a project entitled »The physical modelling of torch fires«. The project was a part of the CEC research programme »Major Technological Hazards« (MTH), and involved research groups from a number of European countries. The aims of the project were to investigate horizontal natural gas jet fires in the atmospheric boundary layer, and describe the transfer of heat to objects impinged by the fire. The exit velocities used were moderate relative to that of sound, explaining the use of the word »torch«. Both theoretical and experimental work was done including 1D and 3D modelling, small-scale wind tunnel experiments and the large-scale experiments performed at Risø.

The department's part of the project was carried out in collaboration with Risø's Combustion Research Department, with help from the Risø departments of Engineering and Computer Science, and Meteorology and Wind Energy. The work consisted of building up the facility and performing two series of experiments. The first was a characterization of the free flame at various exit velocities under varying meteorological conditions. In the second series heat transfer to an object (long vertical cylinder) placed in the flame was measured. The measurements included temperature profiles, heat radiation near the flame, infrared video recordings (thermography), heat transfer to the object, boundary layer meteorology (wind profiles, wind direction and turbulence) and gas exit temperature and velocity. Figure 2.4 shows the heat transfer to the cylinder. The largest values are foun d on the side facing the burner.

A 1D model developed by groups at Universidad Politecnica de Madrid and Politecnico di Milano was able to reproduce the wind tunnel data quite satisfactorily in terms of temperature levels and flame geometry, whereas the larger flame is less well described. On the other hand, corresponding estimates of radiation levels in the surroundings of the flame agree more closely with the large-flame data than with the wind tunnel data.

In the summer of 1991 a new project was initiated called Jet-fire interactions with vessels containing pressurized liquids (JIVE). JIVE is a project under the CEC research programme STEP. Not less than 12 groups from 7 European countries participate. The main objective is to study one particular type of accident in which a vessel containing a flammable liquefied gas (e.g. propane) is heated by a jet fire. The heating, and subsequent pressure buildup combined with weakening of the steel, eventually causes a complete rupture of the vessel, leading to a dramatic escalation of the fire. Both the implications of the failure of the vessel and the conditions leading to the failure will be studied. Experimentally this is approached along various lines. Perhaps the most spectacular one will be the experiments to be performed by British Gas, Shell and HSE in which the accident will be simulated in full scale using a 2000 MW jet flame generated by high-pressure two-phase releases of methane, LPG or mixtures containing higher hydrocarbons (simulating condensate).

Risø's role is to characterize the natural gas flame and measure the heat transfer to a plate placed in it. As was the case for the MTH project, the department is collaborating with the Risø Combustion Research Department. The new experiments have been under preparation in 1991.

Publication in 1991: 43.

2.7 Atmospheric Dispersion

In 1991 a Ph.D. project was finished. The title of the final report, which will be issued in 1992, is »Perturbative methods in turbulence and turbulent diffusion«. The project is a theoretical investigation of perturbation theory applied to fully developed isotropic and homogeneous turbulence and turbulent diffusion. A systematic approach similar to Feynmann diagram expansions used in quantum field theory has long been known, but there are certain problems with the method due to the appearance of spurious divergences. For this reason the method has been rejected by many researchers. The diagram expansion is reviewed in detail and the origin of the divergences is identified.

It turns out that divergences in the limit of infinite Reynolds' number are physically sound for quantities that are not Gallilean invariants, while Gallilean invariants should not diverge in this limit. Closely related to this is the fact that the invariants obey Kolmogorov scaling in the inertial range while the non-invariants do not. The problem with traditional approaches, like the Direct Interaction Approximation, is that Gallilean invariants are approximated by means of non-invariants, and inherit their divergences (rendering them spurious). An alternative method is given for making systematic approximations to invariants, involving only invariant quantities, and it is shown explicitly how divergent terms cancel when the »bare« diagrams are grouped in a particul ar way. Based on the lowest-order approximation in this scheme plus some rather crude approximations to the resulting integro-differential equations, the Kolmogorov constant is estimated to be 1.29, which is within 20% of most experimental values.

The problems of single-particle and two-particle diffusion are also addressed. An estimate of the ratio of the Lagrangian integral time scale to that of the energy dissipation is given. It almost coincides with the experimental value (which is, however, not that well established). The two-particle problem is perhaps more interesting, but also more difficult. An estimate of the constant in the Richardson-Obukhov law is given, based on the lowest-order approximation. It is concluded that an approximation of higher order is needed here. This task is left for the future work.

Risø is also participating in the dense gas dispersion project FLADIS under the CEC research programme STEP, which was initiated in 1991. The Department of Meteorology and Wind Energy holds the contract with the Systems Analysis Department as a subcontractor. The task of the group is to develop a dense gas dispersion model based on the so-called shallow water equations. Potentially such a model can incorporate important features such as the effects of complex terrain and blocking/channeling caused by the presence of buildings. In 1991 a prototype was made for the purpose of estimating computer demands and identifying of numerical difficulties.

2.8 Reliability Analysis

In 1991 two specific projects were carried out using the methods and models developed for the purpose of reliability analysis: one for DSB, Danish State Railways and one for DMI, Danish Maritime Institute.

The DSB project was initiated in 1990. It comprised a reliability analysis of the technical installations in the Great Belt Link between Zealand and Funen with respect to the possibility of disturbances in train traffic due to equipment failures.

The reliability analysis comprised the components and equipment in the following systems: instrumentation and control, power supply, catenary system, mechanical installations, (e.g. pumps, ventilators and cooling units), signalling and block system, safety systems and section

block, radio and remote control and railway track system.

The project was divided into three phases:

Phase I was carried out in 1990; it comprised the reliability requirements in the tender design material for the individual components and units. Phase II was carried out in of 1991 and concerned a qualitative reliability analysis. All of the systems were reviewed with respect to their reliability and possible influence on train traffic due to equipment malfunctioning. An overall reliability model comprising the power supply and instrumentation and control systems was established. Phase III comprised the required reliability calculations on the basis of the model which was established in phase II. The data concerning the frequency of the basic events in the model were obtained from the suppliers of the equipment and from »Reliability Data Book« for components in Swedish nuclear power plants. The analysis comprised such equipment failures that could cause interruption of the train traffic in one main tunnel and in both main tunnels as well as failure of the high-voltage power supply to one of the cross-tunnels. The main result of the analysis was that no weaknesses were identified in the design of the systems that could cause an unacceptable frequency of interruption of the traffic through the main tunnels. One of the conclusions concerns the possibilities of false alarms. It is recommended that sufficient precautions be taken by the final design of the sensor systems in order to avoid unacceptable disturbances of the train traffic caused by such alarms.

Under contract with the Danish Maritime Institute (DMI), a risk study of alternative port designs has been initiated. The aim of the study is to compare for a ship of given type and size the alternative designs with respect to the possibilities of

- a collision between ship and border of the approach channel,
- grounding in the channel and
- a collision between ship and breakwater, quay, or another ship in the port.

On the basis of positional data of the ship obtained from DMI's ship manoeuvring simulator (steered by a human pilot), risk indices have been derived for the horizontal collision possibilities.

The probability that the ship will ground in the channel will be determined by means of Monte Carlo simulation. By this simulation most of the parameters determining the actual underkeel clearance are considered stochastic variables, e.g. the vessel response to waves (heave, pitch and roll) and the water level variation due to tide and waves. On the basis of wind and wave statistics, probability density functions for the vessel response and the water level variation are derived by DMI and the Danish Hydraulic Institute.

2.9 Risk Analysis Projects

The Risk Analysis Group has extensive experience from a large number of research and application projects in the field of risk analysis. In 1991 the risk analysis activities have included: developing and testing guidelines for safety reports, developing guidelines for preparing risk analyses and making integrated assessments of environmental and occupational impact of new materials.

The EEC directive on major accidents of certain industrial activities (82/501/EEC) has been in operation in Denmark for several years now. Therefore, in accordance with Danish orders and regulations, a large number of manufacturers have prepared a notification for the authorities containing a safety report. With regards to volume, organisation, procedure and content these safety reports vary significantly. In 1990 a Nordic co-operative project was initiated on »Developing and testing of guidelines for safety reports« which is planned to be finished in 1992. The project is financed by the Nordic Council of Ministers and the work is carried out by the Technical Research Centre of Finland, Risø National Laboratory and representatives from the relevant authorities in Denmark, Norway, Sweden and Finland.

The main purpose of the project is to develop and test practical guidelines for preparing safety reports and to suggest criteria for evaluating the acceptability of risks. The preliminary version of the guidelines has been discussed at a project seminar and the applicability and quality of guidelines will be evaluated in the next development phase of the guidelines. For that purpose an example of a safety report has been prepared which is intended to be used as a test case. The example is based on the previous production of the herbicide phenmedipham at the Danish company Køge Chemical Work Ltd. The safety report example has been structured in accordance with the CEC directive on major accidents of certain industrial act ivities to illustrate the frame of a notification to the authorities. The safety report contains descriptions and assessments of those parts of the activity which are the most important from a safety point of view together with a review of the safety precautions and measures installed to protect the employees, neighbours and environment.

In relation to this work a report has been published specifically referring to the Danish orders and regulations. It contains an introduction to the preparation and use of safety reports and risk analyses together with a Danish version of the safety report example noted above. This work has been carried out in cooperation with the Danish authorities, and the target groups for this report are Danish manufacturers, a uthorities and consultants responsible for preparing or approving notifications concerning major hazards activities.

The main project concerning the integrated assessment of environmental and occupational impacts of new materials was initiated in 1991. It was financed by the National Agency for Industry and Trade and planned for completion in 1993. It is a part of the Danish programme for developing new materials and is carried out by seven Danish research institutions in cooperation with the Danish Technology Institute as project leader.

In the first phase of the project the five centres for development of new materials have been involved in collecting information and data for assessing the environmental and occupational impact of their materials. The next phase of the project comprises the development of a general life cycle analysis procedure based on the screening procedure developed in the preliminary project and life cycle analysis of selected materials from the five centers.

Publication in 1991: 56.

2.10 Risk Management

Human error is a major contributor to many accidents, where the human in question may be an operator, a pilot or driver. Human error on management levels and in the design process is seldom specified as the prime cause of an accident.

The regulatory bodies in Denmark and other countries have stated that future regulation and control must put greater emphasis on the »organisational factors« in safe operations.

To extend the use of risk analysis from the technical issues into the organisational sphere, the group started a development of a model for integrated safety management. The work in 1991 comprised insurers risk management evaluation and safety culture considerations.

One way to gain insight into integrated risk management conditions and in actual safety cultures is to cooperate with insurance experts and improve tools for integrated risk management and evaluation. Contacts have been made with Danish insurance companies to work on the evaluation of integrated fire safety control with rational methods and better coverage. The evaluation shall integrate the fulfilment of fire safety codes with the education and culture of the users and with contingency plans. Further, experience should be extended from the fire safety area into other safety domains.

To elaborate concepts for integrated risk management and to develop the necessary models of the growth of safety, contacts with the Copenhagen School of Economics and Social Science have been established.

A thorough initiative has been taken to prepare project proposals to be presented to the CEC ENVIRONMENT programme in 1992. The proposals are worked out in collaboration with parties in Sweden, Finland, Norway, England, and The Netherlands. A common heading for the subject areas is »integrated safety management of activities with environment risks«, taking into account national variations in safety culture and multiobjective decision making relevant to environmental risks.

3 Cognitive Systems Group

Despite the fact that information technology is causing profound changes to work situations in all sectors of society, surprisingly little has been done to make computer systems truly usable. Poor design of the user interface is not only an inconvenience to the operators of the systems, but also a source of mistages and errors that may lead to hazards or accidents. The basic problem of matching the rich technical possibilities offered by IT to the human cognitive capabilities is the key research issue in the Cognitive Systems Group. The Group primarily focuses on the cognitive demands imposed by high-tech work settings with a view to translating the knowledge into good interface design practice.

A significant milestone in 1991 has been the creation of a new partnership between the Group and Center for Cognitive Science at Roskilde University under the heading Center for Cognitive Informatics - CCI. The objective of this joint effort is to develop Danish cognitive science and engineering, to increase collaborative international links in the field and to achieve information dissemination and technology transfer.

Since 1989 the Group has coordinated two research projects under the CEC ESPRIT-II programme: (1) ISEM (IT Support for Emergency Management) and (2) MOHAWC (Models of Human Action in Work Context). Both will expire in 1992. In 1991 the Group participated in European consortia addressing the third CEC framework programme in the areas of information technology (ESPRIT-III), telematic systems (TELEMATICS) and advanced communications technologies (RACE-II).

By the end of 1991 Jens Rasmussen retired from his post as Research Council Professor at Risø and the Technical University of Denmark. He will continue his affiliation with the Group as consultant.

3.1 Center for Cognitive Informatics - CCI

The Group's partner in CCI - Center for Cognitive Science at Roskilde University (CCS) - is an interdisciplinary, collaborative enterprise ministered by academic staff at four departments: Modern Language, Mathematics and Physics, Computer Science and Communication Science. CCS is directed by Research Professor Niels Ole Bernsen, who also leads CCI.

CCI is more than just a structure set up to coordinate and integrate a number of interrelated scientific activities. The agreement to establish the Center obliges the two partners to utilize their knowledge, experience and resources and to act jointly in their responding to calls for proposals and other opportunities for externally funded research.

The impetus to establish CCI was the acknowledgement of the proposed work as a framework project under Programme for Informatics and Information Technology. This programme extends over a three-year period and is executed and administered by the Danish Natural Science Research Council, the Danish Technical Research Council, and the Danish Agricultural and Veterinary Research Council. The funding awarded CCI has made it possible to hire extra research staff consisting of three scientists in 1991 and to prepare the announcement of further research positions early in 1992.

The planning of CCI's activities is implemented with assistance from an advisory board in which both IT industry and users are represented. The Center's strategy is to carry out long-term basic research, to work on application-oriented projects that will maintain an appropriate perspective on user needs in real-life situations and to develop and test IT prototype systems and interfaces. An important step in implementing CCI is to establish an IT development and testing facility based on modern multimedia.

The plan for basic research is organized around the five interconnected main themes: (1) taxonomies for work domains and tasks based on empirical field studies, (2) mental representations, processes and strategies, (3) user modelling and criteria for interface design, (4) theories of distributed, cooperative work and (5) analysis of adaptive, self-organising systems.

An essential component of Theme 1 is to capture the prototypical characteristics of work domains and tasks along various taxonomic dimensions such as means and ends, skills, rules and knowledge and temporal characteristics. Classifications of this kind provide the overviews needed by designers of user-centred information systems. Theme 2 is important in understanding how IT may support human concept formation and reasoning through natural and graphical language presentations. One of the key issues is to develop logical formalisms for modelling causal reasoning in diagnostic tasks. In Theme 3 the emphasis is on studying computer users' evolution of subjective criteria and preferences with work practice. The overall aims are to develope a systematic approach to interface design and demonstrate the feasibility of user-adaptive IT systems. Theme 4 relates to Computer Supported Cooperative Work - CSCW - where relatively little has been done up to now to clarify the impact on the work organisation of distributed decision making mediated by computers. The last is Theme 5 which has been included to create a forum of discussion where IT is viewed as an instrument for supporting individual and collecttive adaptive, self-organising processes. This viewpoint is useful because of the emphasis placed on error as a necessary ingredient of adaptions.

Under Programme for Informatics and Information Technology, CCI is a participant in a framework project on natural language processing in application-oriented dialogue systems. The project is directed by Center for Speech Technology at Aalborg University and has Center for Language Technology at the University of Copenhagen as its third participant. The three Danish research centres involved have become managing node in an European pilot Network of Excellence in Speech and Natural Language led by the University of Edinburgh.

In 1992 the work in relation to Research Theme 4 will be extended to include empirical studies of distributed cooperative work in the manufacturing industry under an ongoing cooperation with the Department of Manufacturing Engineering at the Technical University of Denmark.

3.2 Computer Supported Cooperative Work - CSCW

Launched formally as a research area as recently as some five years ago, CSCW has witnessed a dramatic surge of interest and creativity and it is now widely recognized as a crucial area in the development of information technology.

CSCW is a highly interdisciplinary research area, involving disciplines as disparate as communication technology, distributed systems, distributed artificial intelligence, organisational theory and development, sociological studies of cooperative work practice and socio-technical systems development. None of which are able to provide the conceptual framework for CSCW as a research area. Hence the development of the theoretical foundation for the design of computer systems to support cooperative work is crucial to the development of CSCW as a research area.

The CSCW research activities in the Cognitive Systems Group therefore primarily focus on the theoretical foundation for CSCW systems design. These issues are being investigated in collaboration with a number of research institutions, in particular within the framework of Working Group 4 of the COST-14 action »CoTech«: University of Amsterdam, University of Twente, the Computer Science Department at the University of Aarhus and BNR Europe. »CoTech« Working Group 4 is funded by a grant from ESPRIT Basic Research.

An important result of the CSCW research activities of the Cognitive Systems Group in 1991 is the development of the concept »mechanism of interaction«. In cooperative work, the individual workers are interdependent in doing their respective work. Due to their being interdependent in conducting their work, cooperating workers have to articulate (divide, allocate, coordinate, schedule, mesh, interrelate, etc.) their respective activities. In doing this, cooperating workers apply an array of different »mechanisms of interaction« that help them reduce the complexity of articulation work:

- Turntaking protocols to handle floor control in real-time interaction such as meetings.
- Classification schemes for indexation (classification, naming) of »public« information objects, e.g., thesauri and taxonomies.
- Organisational structures in the form of formal (explicit, statutory, legally enforceable) and not so formal (implicit, customary, actual) allocation of resources, rights and responsibilities, etc. within the cooperating ensemble.
- Standard operating procedures, prescribed work flows, master schedules, »kanban« systems, emergency plans, etc.

However, a mechanism of interaction cannot mirror the rich multiplicity of cooperative work, and it will therefore inevitably be placed in unforeseen situations in which it is »beyond its bounds«. Accordingly, mechanisms of interaction in everyday working life are being managed

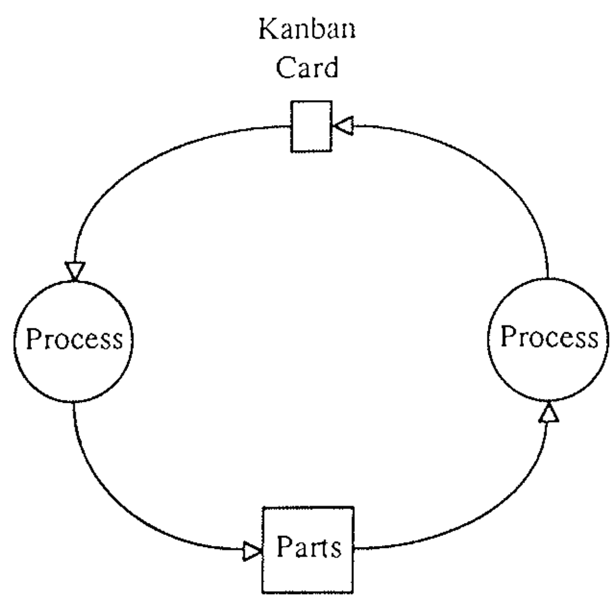


Figure 3.1. The basic principle of the kanban system for production control. As parts are being used in the production process, cards are sent upstream in order to communicate that new parts are needed and are to be produced.

(constructed, maintained, developed, interpreted, applied, adapted, circumvented, represented) in a continuous negotiation process.

For example, in advanced manufacturing a so-called kanban system is used to coordinate distributed activities. The term kanban, the Japanese word for »card«, designates a system where chains of interdependent production processes are coordinated in a »feedback« mode, i.e. on the basis of current demand. The mechanism is simple: A card is attached to a transportation box containing a specific batch of parts, and when the batch has been used, that is, the box has been emptied, the card is sent back to the operator who makes the parts and he then produces another batch (see Figure 3.1).

However, a kanban system has certain limitations; for example, it can only handle small deviations in end product demand. Accordingly, in manufacturing operations that must cope with the demands of a turbulent market and where the kanban system often will be »beyond its bounds«, the indirect, dumb and formal kanban mechanism is subsumed under a very direct, intelligent and an informal cooperative coordination. Thus, in a manufacturing company investigated by researchers in the Cognitive Systems Group, informal networks of clerks, planners, operators and foremen in various functions such as purchasing, sales, production and shipping were cooperating directly in controlling the flow of parts. A decision maker in this network would explore the state of affairs »up-stream« so as to be able to anticipate contingencies and issue warnings in case of disturbances that might have repercussions »down-stream«. This informal network had even »appropriated« the kanban system in order to increase its flexibility. To adjust the number of cards to the needs of the situation, cards would be pocketed or handed over directly, new batches would be ordered before a box has been emptied, batch sizes would be changed, etc. In so doing, they exploited their detailed knowledge of lead times and inventories to control production far more closely and effectively than warranted by the kanban system.

In general, then, a CSCW system must be designed so that it supports users in managing the mechanisms of interaction incorporated in it. A mechanism of interaction incorporated in such a system should be accessible to being cooperatively managed by a large, varying and perhaps indeterminable ensemble of semi-autonomous actors, etc. CSCW systems should therefore support cooperative management of the representations of organisational structures, classification schemes, procedures, etc. incorporated in CSCW systems as mechanisms of interaction. This requirement has radical implications for the design of the user interface of the system as well as for the underlying systems architecture.

The Cognitive Systems Group is widely recognized as a central actor in international CSCW research. The Group was deeply involved in organising the second European conference on CSCW in Amsterdam in September 1991 and is represented on the editorial collective of the first international journal devoted to CSCW. Also, the Group is a founding member of the European Foundation of Co-operative Work Technology.

The phenomenon of mechanism of interaction and the problems involved in incorporating such mechanisms in computer systems are being explored further in an international and interdisciplinary research collaboration involving, inter alia, the Cognitive Systems Group at Risø, the Centre for CSCW Research at Lancaster University, the Computer Science Department at the University of Nottingham, the Departments of Psychology and Sociology at the University of Manchester and the GMD (Bonn). The group has produced a project proposal for ESPRIT Basic Research specifically devoted to the problem of computer-based mechanisms of interaction in cooperative work.

Another international research initiative in which the Cognitive Systems Group collaborates with the Lancaster Centre for CSCW Research and other sites, is exploring the implications for the architecture of workstation and network operating systems of the conceptualisation of co-operative work developed by, inter alia, the Cognitive Systems Group.

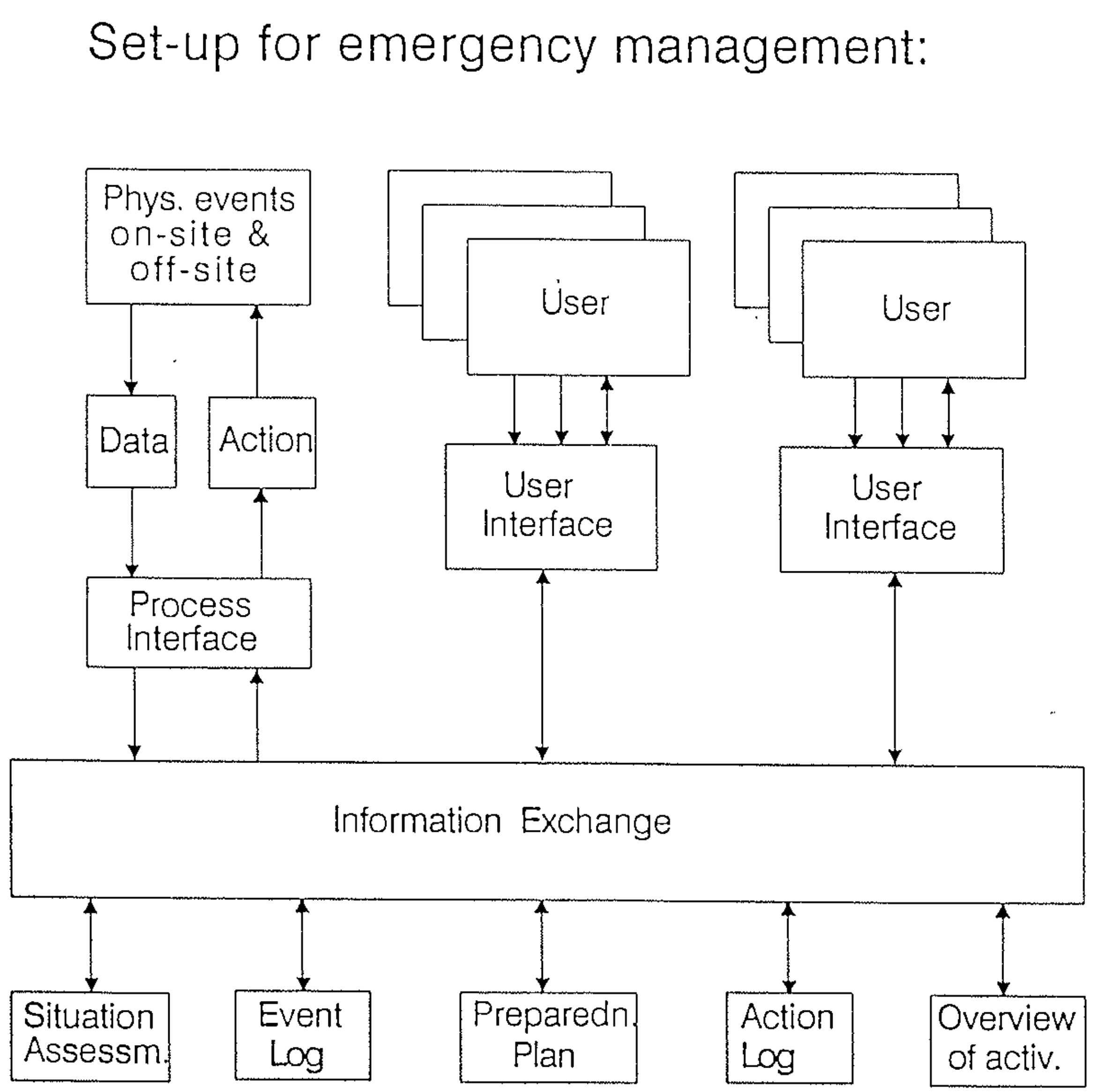
Publications in 1991: 5, 71, 72, 73, 74, 75.

3.3 IT Support for Emergency Management - ISEM

The aim of the ISEM project is to benefit from advanced information technology in coping with complex emergency situations. This is particularly relevant when decision making is needed in an organisation that is distributed regionally.

ISEM began in 1989 and is a joint European project within the framework of CEC ESPRIT.

Figure 3.2. Functional architecture of the emergency management system.



The consortium is rather large, and apart from Risø includes (for the time being) four Danish, four Spanish and one Italian participant representing the European Community; furthermore, the consortium includes one Swedish and one Finnish participant representing the EFTA countries.

In 1991 the work comprised:

- the results of information analysis based on specific CASE tools named Symbion,
- plans for further development, verification and validation tests and implementation, and
- system architecture.

Part of the information analysis study is a thorough description and classification of the objects dealt with in the system, the functionality of the system affecting these objects, and the data model on which the development will be based. From a conceptual point of view the functionality has been grouped in functional modules, depicted in Figure 3.2, which also shows the functional architecture of the system.

The heart of the system is the information exchange module that is responsible for communication among all the various functional modules. A specific part of this module is the message management system, MMS, which is a dedicated electronic mail system used for information exchange amont the users of the system, i.e. the emergency managing decision makers which may be geographically distributed.

The specific logging modules log events and actions to allow for the recording of detailed information about the history of the accident; this is extremely important during the emergency situation as well as during a later post-mortem analysis.

The functionality of the remaining modules indicated on the figure are self explanatory.

As indicated in the figure, the user-interface of the system may be tailored according to the needs of specific users.

The hardware architecture has also been discussed and decided upon. Each part of the total organisation will have access to the system via X-terminals installed on a Local Area Network, LAN, and the various LANs will be able to communicate via X400/X25 protocol. Furthermore, each LAN will be equipped with a SUN database server, PCs prescribed for specific features - e.g. a Geographical Information Systems, GIS - and where needed, a direct access to the process control computer for the plant for which the emergency management system has been installed.

In 1991 the consortium lost two partners, the Danish software house Scaitech, and the Belgian software house CREON, requiring the remaining tasks to be re-allocated. The work of Scaitech has been taken over partly by Modulex Software. The CASE tools on which the project development was based were developed by CREON; hence, they had to be replaced by a new set of similar tools.

By the end of the year a Danish software house, IFAD, was included in the consortium to replace CREON, and the corrections of software specifications had been more or less finalised.

However, as a result of the loss and replacement of the partners, the project has been delayed; it is now scheduled to terminate in August 1992.

It is the intention to evaluate the end result of the project - a decision-support system for emergency management - by developing and implementing two demonstrators in two different areas:

- one inside the nuclear domain to be implemented at Tecnatom in Spain and
- one inside the chemical domain to be implemented at Kommunekemi in Denmark.

A survey of marketing and exploiting the end product has begun. Unfortunately, the market does not seem sufficiently mature for the time being for a complete ISEM system. It is clear that full benefit of the system would be derived only if all parts of a total organisation were to have access to the system, and this would require a political decision. However, the survey has given very promising indications about marketing of the ISEM systems by parts, as the full-scale ISEM system will be developed in modules that could be used separately.

Publications in 1991: 3, 4.

3.4 Models of Human Action in Work Contexts - MOHAWC

The MOHAWC project is an ESPRIT Basic Research Action. The project aims at integrating and elaborating models of man-machine interaction and of the behaviour of human agents in complex work environments. It was started in 1989 and will finish in early 1992. The project consortium, which has been led by Prof. J. Rasmussen, Risø, comprises eight partners (JRC-Ispra, Univ. of Manchester, Univ. og Liège, Univ. of Bamberg, Univ. of Paris VIII, Univ. of Uppsala and Roskilde University Centre).

The objectives of the project are reflected in the four topical workshops arranged during the project period: while two workshops were held in the preceding year (on »Taxonomy for Work Analysis« and on »Models of Cognitive Processes«) the consortium arranged two successful project workshops in 1991 (on »Distributed Decision Making« and on »Simulations and Validation of Models«). A final joint workshop will be held at the beginning of 1992 in collaboration with two other ESPRIT Basic Research Actions (KAUDYTE and AMODEUS). Each of the four MOHAWC workshops has resulted in a set of workshop proceedings published by the Cognitive Systems Group.

A major achievement of the project has been the development of a so-called taxonomy for cognitive work analysis. The taxonomy comprises a theoretical framework and classification of human-machine or human-system interaction. One of the chief goals of the taxonomy is to provide a framework in terms of which results from different studies of human behaviour, in given work domains or task settings, can be compared. In particular, the taxonomy provides a common frame of reference allowing results from field studies and experimental studies to be compared. In this context, field studies refer to examinations of how humans cope with real tasks in real work domains such as control rooms, emergency management, hospital operating rooms; similarly, experimental studies refer to empirical investigations of how humans cope with tasks presented in, for instance, simulators or other kinds of experimental settings.

The work conducted by Risø in 1991 has been divided into five separate study programmes.

First, continued efforts at elaborating the taxonomy of cognitive work analysis resulted in the publication of a comprehensive report about »prototypical work situations and their implications for the design of Information Technology (IT) systems«. This work, on the one hand, describes and summarises results from studies of human-system adaptation and, on the other hand, lays down guiding principles for designing IT systems which support useful user adaptation. A key concept proposed for this purpose is that of a prototypical work situation (PWS). The concept of a PWS covers, (1) a characterisation of the relevant work domain, (2) the set of task situations and (3) the set of users' competence profiles. This work is currently being elaborated into a textbook which is scheduled for publication by a North American publisher.

Second, previous work on a simulation of forest fires has continued. It has led to the development of the so-called NEWFIRE microworld, which is a computer-based experimental 'game' suitable for testing a great variety of parameters concerning task characteristics and human subjects. This has been the result of close collaborative efforts between Risø and Uppsala University, the latter institution having designed the precursor of NEWFIRE for studying human decision making. The continued work on the NEWFIRE program, inplemented in Smalltalk, has resulted in an experimental software environment which has proven to be very flexible, and the program is now used at several sites throughout Europe. In 1991 NEWFIRE was extended to include a robust algorithm that enables the experimenter to analyse fire scenarios with a view to determining the optimum strategy for deploying fire fighting resources in the initial stage of a forest fire.

Third, a series of empirical studies and simulations of adaptive behaviour has been carried out and will continue for the duration of MOHAWC. These studies have consisted in, (1) the collection of empirical data from subjects coping with a computer game requiring a high degree of dexterity and coordination and most importantly (2) the development of a simulation model aiming at representing the way subjects learn to master the game.

Fourth, field studies of distributed decision making in manufacturing have been carried out at two Danish companies which design and manufacture consumer products. The studies, which were planned to follow the guiding principles of the MOHAWC taxonomy (cf. above), confirm the view that design decisions are arrived at by the various agents and organisational units by reasoning in terms of means-ends and part-whole. The study has led to the production of an outline of a general architecture of distributed decision making in modern manufacturing industry.

Fifth, a field study of distributed decision making in emergency management was started. The target company is a large waste disposal plant dealing with relatively hazardous materials. The study has compared the flow of information during routine operations and emergency situations and it has sought to identify the decision strategies adopted by the emergency personnel during cases of incidents. A spin-off of this effort will be the requirement analysis necessary for developing a prototype emergency management system. This system, the development of which is funded by national sources, is planned in close cooperation with the ISEM project.

Publications in 1991: 6, 23, 24, 35, 36, 55, 57, 60, 71, 72, 73, 74, 75, 76.

3.5 Cognitive Simulation

What actually happens when people learn to use information systems? Modelling human acquisition of skills in technological environments contributes to an answer to this question, and has become an important research topic within Human Computer Interaction. Computer models of human adaptive behaviour make it possible to test for their consistency, and compare their predictions with the actual performance found in empirical experiments and field studies. In the ESPRIT-II MOHAWC project a computer game is used as one type of testbed for cognitive modelling, because such a game represents a work domain of highly limited and well-known alternatives for action.

First, the computer model has to learn to play the game (a commercial Commodore video game called »Gymnastics«). Then we can compare the performance of the computer model with that of an individual and modify the model until it shows the same behavioural trajectories as those typically shown by our experimental subjects.

A major difficulty with a Commodore game consists in deciphering what actually happens in the computer when a subject or the model operates the joystick to perform a manoeuvre. By analyzing the Commodore code it was noted that the postures taken by the gymnast are internally represented by sprite numbers which may be recorded along with the joystick positions to produce the desired experimental information. We developed a PC emulator of the Motorola MCS-6510 processor in the Commodore-64 and now possess a PC tool that enables us both to replay experiments performed earlier by 21 teenage subjects and go ahead with developing a simulation model written in a language such as C.

The implementation of a simple hill-climbing algorithm based on the goal to obtain maximum scoring by trial and error has demonstrated the basic ability of the computer model to learn to master the game. But the performance of a hill-climbing model is far too simple and efficient compared to that of humans, as it possesses a perfect memory for prior events and a precise timing of all its manoeuvres. To resemple human performance, the hill-climbing model must be handicapped by a reaction latency in its cue-action rules, by stochastic variations in its timing abilities and by restrictions on its memory of prior events. Moreover, the model is unable to generate new action strategies, and therefore it needs to be informed of all action possibilities and their approximate timings. Without the ability to generate new action rules, the evolving action patterns produced by a hill-climbing simulation model tend to become stable in regions of the event space where the scoring has a local maximum. We are now attempting to outline the details of a model with these features in a final MOHAWC deliverable.

3.6 The Book House System for Information Storage and Retrieval in School Libraries

A methodology for cognitive work analysis has been developed in the MOHAWC project at Risø in order to aid designers of information systems develop consistent empirical analyses of different work domains as a basis for laying down functional system specifications. Following this methodology is an undertaking that consumes time and resources to an extent that precludes its use on every system design. This theoretical work has therefore been continued in 1991 as an attempt to (1) delimit the methodology and focus instead on some basic properties of different work domains, (2) focus on the design of ecological interfaces for information systems and (3) use the limited, basic properties of work domains as a basis for the generalization of ecological interface specifications in one work domain to interface design in another. For this purpose, the Book House system developed at Risø for information retrieval in libraries has been used as a design case.

The properties of work domains vary along many dimensions of Risø's cognitive work analysis, and as a first step the limited analysis focuses on prototypical work situations, that is, typical examples defined by the three dimensions of the Work domain - Task situation - User profile

(WTU profile) and their interrelationship. In order to explore this approach, a selective categorization of appropriate sets of WTU profiles has been studied in the domains of libraries, process control and manufacturing in an attempt to identify prototypical situations.

The properties of ecological interfaces limit the content of the interface specifications to the invariant properties and state of affairs in the work environment. This means that the regularity of users' behaviour in a work domain which comes from a combination of functional and intentional constraints on users' action possibilities is limited, depending on the type of work system considered. The graphical form of ecological interface displays is determined by user profiles and characteristics and his or her professional, phychological, social and cultural background.

In particular, prototypical work situations of information storage and information retrieval in public libraries and in school libraries have been analysed. This has been done for the purpose of comparing and generalizing the functional system specifications of the Book House interface derived from a cognitive work analysis in public libraries to interface design for similar prototypical work situations in school libraries.

A comparison of the Domain Characteristics showed some similarity in intentional invariants in coordinating work processes derived from financial constraints, library legislation, institutional policies and socially established rules of conduct. This similarity extended to a user's values and intentions in using the library, as derived from each individual's behaviour patterns in retrieving information. This intentionality is reflected in the principles used in designing the Book House system, and can be immediately generalized to school libraries. However, in school libraries an additional constraint is derived from the legislation with respect to the role of schools in public education and in policies for teaching curricula in various disciplines.

On comparing of the Task Situation Characteristics of information retrieval and storage in school and public libraries, we were able to identify the same kind of analysis and comparison of users' needs and the same »work space«, which is basically a collection of books that has no context-independent, functional structure. As a result of this, the user's own conception of his or her information requirements is the basis for structuring the database system and indexing information This user search for information was recorded in public libraries and can be generalized from the Book House for public libraries to a Book House for school libraries.

The User Profiles represent a wide cross section of library users with a great variety of characteristics and tasks, in public as well as school libraries. An exception is the well-defined age group of school library users of varying educational levels and tasks, which can be used to determine their various levels of perception of information. Therefore, the overall organising principle for interface displays cannot be related to one particular problem space or user category. The Book House metaphor is a symbol of a library taken from another context familiar to users and can be used equally well in school libraries to support navigation through easy analogies.

In order to evaluate and further develop this methodology the Book House system has been transferred to school libraries based on identified differences and similarities in those aspects that enable the system to function effectively. This required that a new iconic interface be designed to support the school library users' task of book indexing and storage. To complement this, the PC version of the Book House system has been redesigned and reprogrammed for the Macintosh. It was decided to use OMNIS 5 as the underlying database in a SuperCard project, since OMNIS 5 would give the added benefit of being easy to transfer the application to a PC version of OMNIS 5 running under Microsoft Windows. SuperCard can be used to build applications which use the graphical, hypermedia capabilities of a Macintosh computer. Apple Computers A/S, Denmark, arranged six Macintosh LC computers for evaluating the software in five different school libraries, all participants in the project together with the Danish University for Educational Studies, the Institute for Library Services and Technology and Informatics Center in Copenhagen. In order to achieve an acceptable stability and speed on the Macintosh LC, a C++ version of the first preliminary version of the new Book House was ordered and put into operation at the end of 1991.

An evaluation program has been set up to evaluate the efficiency of the redesigned system and of the applied design methodology. The first experiments involve expert users, i.e. school librarians performing information retrieval, book indexing and storage tasks. Data will be collected to answer users' responses to the following system properties: Can the representation of domain invariants in the interface be understood by users, and does the interface display forms accurately match users' perceptual characteristics? Are all the relevant cognitive retrieval and indexing strategies supported? Does the database content support the relevant decision tasks? Does the system functionality support users' intentions and information needs in the task repertoire of their individual and cooperative work situation? Finally, users will be interviewed about their attitudes towards the Book House system in school libraries in order to test whether it actual improves the quality of their work and whether they like to use it, which is a condition for users' acceptance of a new system.

Publications in 1991: 49, 50, 51.

3.7 Multimedia Laboratory

Interfaces for user-centered information systems will develop along two important dimensions towards the next century. The introduction of multimedia will bring a broader range of information sources to the systems by integrating text, sound, voice, graphics, photo, video, animation and telecommunication. The techniques emerging within »virtual realities« (e.g. data-gloves and head slaved displays) will give a deeper interaction with the system, exploiting a variety of human senses and input/output channels to make the interaction more natural and efficient.

The full utilization of the multimedia potentials calls for researching the structuring of multiple informations and models of user interactions with complex systems. In the Cognitive Systems Group, years of research in domains like process control, operation planning in hospitals and manufacturing have provided a framework for cognitive task analysis and interface design, as well as a deep understanding of computer technology. This knowledge is well suited for designing multimedia systems aimed at a high functionality and high usability.

The Cognitive Systems Group is now establishing a multimedia laboratory for developing and testing experimental prototypes in relation to basic research within Human Computer Interaction and EC projects on emergency management, medical diagnosis, Computer Supported Cooperative Work and library databases. The high usability and compatibility of multimedia development tools makes it possible to create impressive prototypes within a short time. Hereby, our principles for interface design can be illustrated on domain-specific applications, and thus form an important asset for establishing projects with research colleagues and industrial partners.

The technical concept of the multimedia laboratory consists of hardware and software with the potential for building applications which integrate the above mentioned information sources. An important aspect of the lab is data capture capability. The laboratory is equipped with a video camera, a still video camera, a colour scanner and a CD ROM unit, and it can access data from conventional networks. Data may be converted and stored on a number of devices ranging from conventional hard disks to optical read/write disks to videotapes. The laboratory can present output on printers, TV monitors, loudspeakers and computer monitors. The central processing power in the laboratory will be provided by Macintosh computers and IBM-compatible PCs. In the last part of 1991 the build-up of the laboratory began by defining the hard- and software components of the laboratory. Figure 3.3. gives an overview of the laboratory configuration.

3.8 Time as the 3rd Display Dimension

As a partial fulfilment of a Ph.D. thesis in cognitive engineering, new interface formats for complex dynamic systems have been developed and empirically tested.

Within a technical domain many aspects of the system behaviour are revealed in a temporal order, e.g. heat transfer across sub-systems or mass- and energy-conversions, and these events are controlled by timed sequences of operational actions. Most of the process functions will exhibit some kind of cyclical patterns or recurring events. Discovering their temporal structure will increase the feeling of familiarity with a complex system and increase the likelihood of an early detection of deviants from normal plant behaviour.

The supervision of trends, gradients of changes, process response time and other time-dependent events are aided by interface representations of the fluctuation of plant data over time. But in present day control rooms, the information support for extrapolations of system states is often provided by strip charts located out of view of the operator's central control position.

To avoid this fragmentation of central infor-

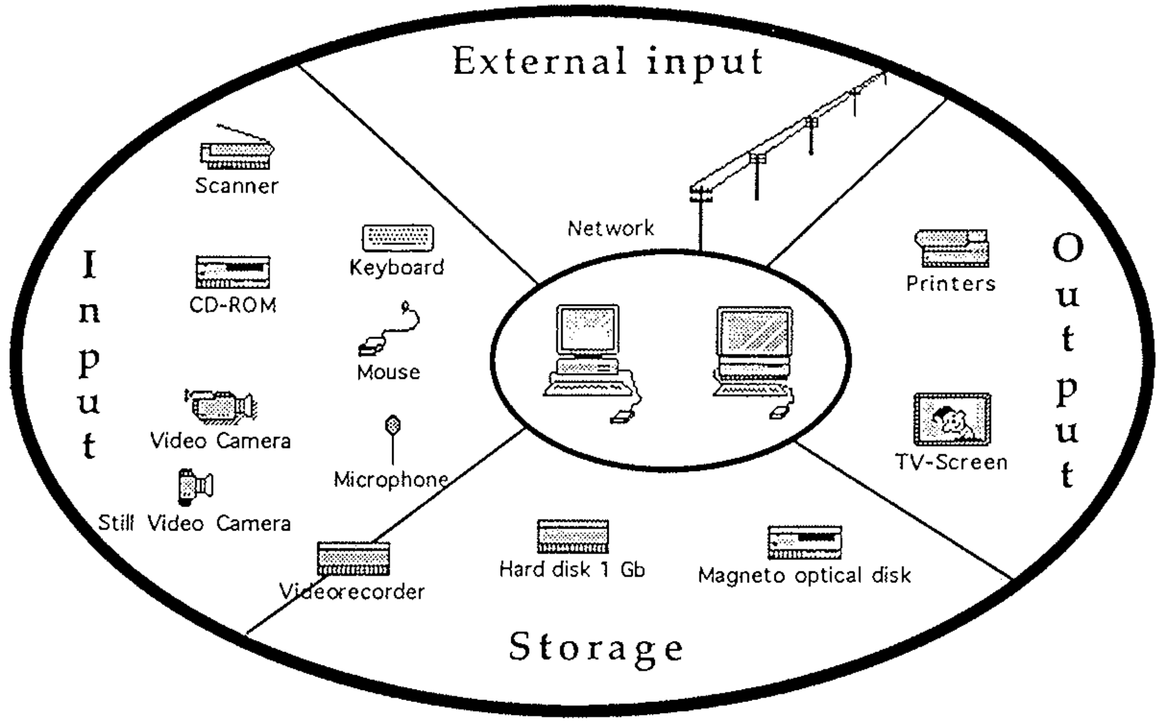


Figure 3.3. The multimedia laboratory equipment.

mation, it is a design challenge to integrate the temporal information in a display format that shows the development of system states within clear indications of the unbreakable constraints of the technical system. Giving time a display dimension for itself is an obvious way to specify the temporality of functions generating the system states, as is seen on, e.g. time curves. But the central control displays commonly occupy the two dimensions by other physical entities or use them to create a spatial analogy to the placement of the system components in, e.g. mimic diagrams.

Thus, it seems a natural design possibility to apply the third dimension for the display of temporal information. We have termed the display of time at the depth dimension »Time Tunnels«. As an example, they may show the information of four incoming data, representing a coolant cycle, as a quadrangle in front (see Figure 3.4), that pushes nine older sets one step »backwards« at each updating, using perspective to map time over to depths. This gives the sketch of a tunnel, with the impression somehow like looking backwards from the last car of a roller coaster while the props pass by. As the process moves further in time, the figure shrinks into the distance and new measurements appear in the foreground. Symmetry or asymmetry in the pattern over its depth reveals patterns and changes in the relationship among the four variables.

From this representation it can be seen whether the process falls or rises, whether it is continuous, and how the relations between the four integrated data have developed. It is intended to provide the operator with an intuition (i.e. a »system feeling«) of e.g. »being in a stable state« or »in a decreasing state« and alarm him when the developments begin to deviate from normal.

During a half-year visiting research fellowship in 1991, an experiment in collaboration with Wright State University and Wright Patterson Air Force Base, Dayton, Ohio, has investigated the perception of trends (i.e. simultaneous decreases on eight parameters) on the time tunnel display with other separated and integrated formats. Compared with other display formats, the utilization of the third dimension in the time tunnels was found to increase significantly the number of correct responses under noisy data conditions. Under current discussion is how the utilization of the third dimension in process control displays may be further improved by means of the new technics available for displaying dynamically perspectives emerging within the area of artificial realities.

Publication in 1991: 26.

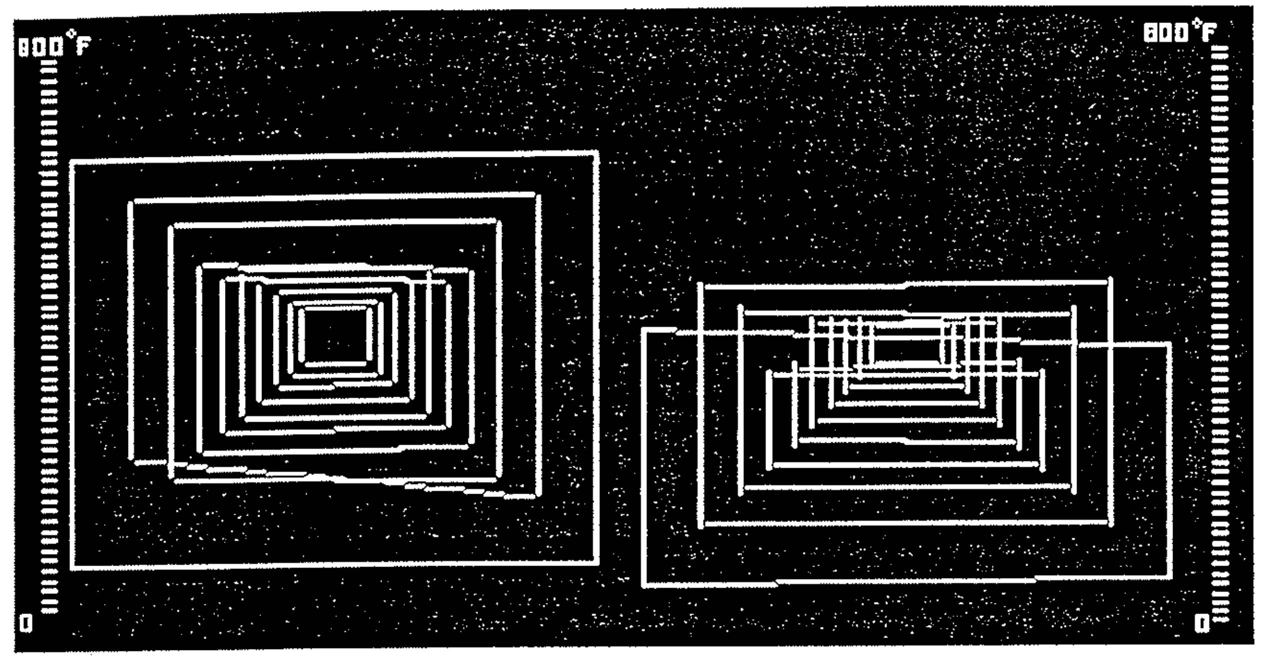


Figure 3.4. Two time tunnel displays of two coolant cycles in an unstable state. Previous measurements shrink into the background at each new updating of the display.

3.9 Knowledge Structure in a Computer-Simulated Environment

This Ph.D. project was begun three years ago and has been completed in 1991. The purpose of the project was to examine how humans are able to control a dynamic computer-based task. The project focused on how a person's knowledge structure and mental models are developed and adapted in connection with task performance in a computer-simulated environment. In order to solve a computer-simulated task the person has to develop a mental representation of the task. This mental representation both controls the task and is influenced by it.

The computer-simulation which was used in the study was the NEWFIRE Forest-Fire »game world« developed as a contribution to the MOHAWC ESPRIT-II Basic Research Action (see section 3.4). Eighteen subjects participated in the experiments performed in the study.

Knowledge structure in computer simulations deals with how people integrate knowledge from different domains. In a game world people have to consider the phenomena from three domains in order to establish a mental model of the simulation: (1) the domain of reality (the semantics to which the simulation refers), (2) the domain of the simulation (the game world) and (3) the domain of the interface (the state of affairs in the game world). Even though the simulation refers to a domain of reality (a forest fire), it has characteristics which are not to be found in the real world settlements. The simulation differs in some aspects quite radically from reality.

Experiments have shown that the subjects in the beginning (in the first trials) think a lot about the semantics of the simulation in order to control it. They make use of their »intuitive« knowledge of forest fires which originates mainly from their experience with different kinds of fires. Later on they develop a behaviour of control which strongly refers to the simulation (the game world). They act and think on the premises of the simulation as it is represented on the computer screen. At this stage they consider only real-world characteristics if they can profit by them in their actions of control. On the other hand, little or no consideration is paid to the nature of those phenomena that the subjects cannot control, but which nevertheless are important task characteristics.

The experiments also show that the subjects often possess or develop particular beliefs about the computer, especially the registration of the mouse clicks. Therefore, they tend to develop an

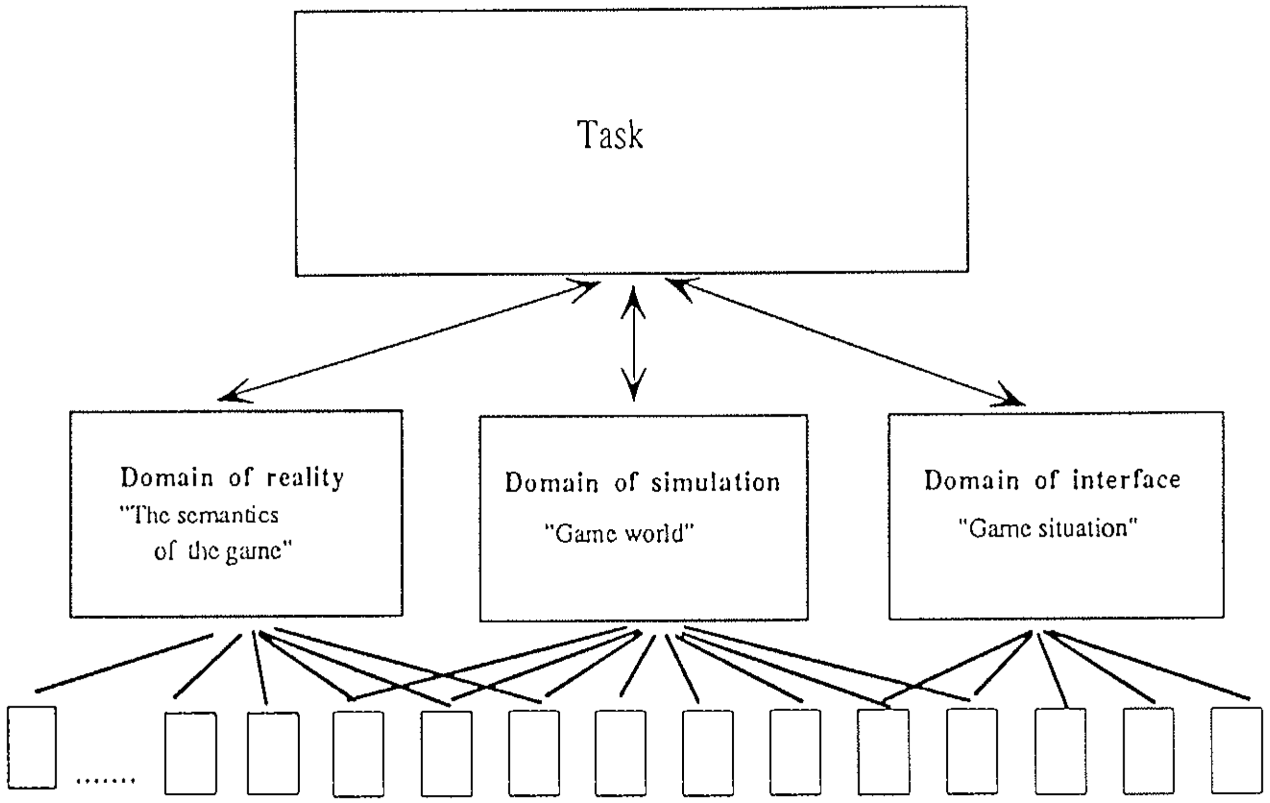


Figure 3.5. Task characteristics of the Forest-Fire microworld.

inadequate behaviour pattern that makes them feel more secure in their actions, such as clicking on the mouse several times even though one click is sufficient.

Another phenomenon that showed up was that the subjects frequently acted before collecting appropriate information. They put their trust in the iconic information on the screen and tended to ignore important »written« messages. Acting before thinking requires only little mental effort and is an aspect of the way people tend to economise on their mental resources.

To sum up - people have difficulties in shifting from one domain of reference to another during a task performance, resulting in instability in their mental models of the system because it changes according to the domain of reference. This means that they may forget important lsystem characteristics, and gradually develop a mental model that is primarily based upon stereotyped actions, found to be appropriate on different occasions during task performance. The mental model is also »unscientific«, because people distrust the system and develop and maintain superfluous behaviour patterns. If failure occurs it is first of all assumed to be the fault of the system.

We have learned that the mental models of most people are not neat or elegant but messy, incomplete and indistinct. Yet we also see that people often are able to control a system despite this.

The results from the project indicate that there are important considerations which must be made in connection with system design. Designers must develop systems and instructional materials that aid users to develop more coherent, usable mental models. It is important to avoid or tone down the use of different domains of reference in system design. The use of methaphors, for instance, has to be considered very carefully. The designers have to take into account that the users want to invest only little mental energy in coltrolling the system. What is obvious to the designer is not necessarily obvious to the user.

4 Energy Systems Analysis

The activities in the Energy Systems Group (ESG) involve integrated energy, economic and environmental modelling and assessment of energy and environmental technologies.

Within the frame of energy and environmental modelling, the group conducts basic research on the analyses of energy systems and develops tools and methods which are applied to a wide range of problems. The group participates in overall Danish energy planning and the process of establishing the framework for this planning.

The environmental aspects of energy conversion and use continue to attract attention in energy planning, and its analysis is one of the main activities of the group.

In 1991 the group has continued its participation in the energy and environmental modelling programme of the European Communities involving the macro-economic model HERMES and the Energy Flow Optimization Model EFOM. Within the framework of the Nordic Council of Ministers two projects have dealt with electricity production versus energy savings and the consequences of the EC internal market for the Nordic countries.

The group participates in Danish, Nordic and European research programmes and contributes to energy and environmental planning projects.

The group is also involved in energy planning activities in Third World countries, and participates in energy planning projects in Eastern Europe.

4.1 Integrated Energy and Environmental Models

More than 50% of all CO_2 emissions to the atmosphere originate from the use of fossil fuels in the energy systems. It is important to describe the possible options for decreasing these emissions thus reducing their environmental impacts.

The Brundtland Scenario Model (BRUS) is a long-term simulation model which was constructed for use in the latest Danish energy plan, »Energy 2000«. In the model energy demand and supply are treated in an integrated fashion, allowing demand-driven scenarios for the total Danish energy system to be calculated. The model includes data on energy supply and end-use technologies, as well as up-to-date data on emissions of pollutants.

The main features of the model are:

- it is a long-term simulation model, looking ahead to the year 2030,
- it is subdivided into different sectors of energy demand and supply, which are integrated to provide a useful and comprehensive tool,
- energy demand and the development of energy production capacity are driven from the demand side,
- it is possible to choose different saving options for building insulation, electrical appliances, and processes, and
- it is possible to choose from a large number of energy conversion technologies.

The main results of the model are gross energy consumption split into different fuels, emissions of CO_2, SO_2 and NO_x, and finally, the capacity and economic consequences of the set up of the chosen system.

The structure of the model, as shown in Figure 4.1, consists of submodels starting with society at large, demand modules for domestic purposes and industry, supply models related to the production of electricity and district heating, and models concerned with emissions and economic consequences. This modularity gives possibilities for partial recalculations, thus obtaining quick answers to partial questions.

The model was constructed using commercial spreadsheet software and its details are specific to the Danish case. The methodology and general model structure are however applicable to other national or regional energy systems. In 1991 the model was used for evaluating the introduction of hydrogen as an energy carrier in the Danish energy system (see chapter 4.7).

Publications in 1991: 37 and 38.

4.2 The HERMES Model

HERMES-DK is a macro-economic medium-term model developed for and used by the CEC. Identically structured national models have been developed for all the EC countries, and the national models are linked to form a multinational model. Each HERMES model describes the energy-economy interactions and economic mechanisms of fuel substitution by treating energy as a

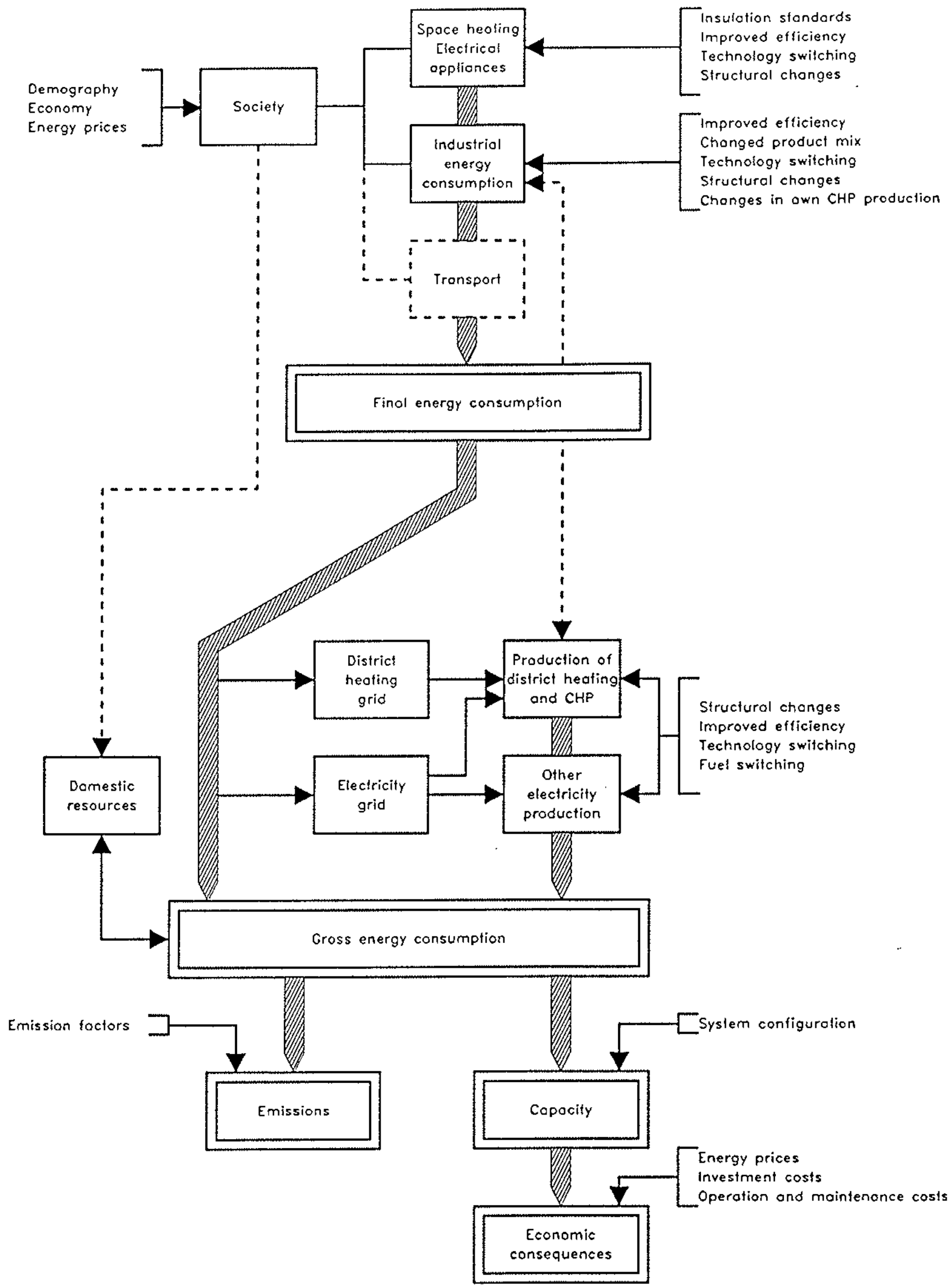


Figure 4.1. The structure of the BRUS model.

production factor, as a specific production branch, and as a component of final demand.

During 1991 the data of the model were updated and the model was used to forecast the overall economic development and to analyse the macro-economic effects of an energy tax of 10 US$ per barrel.

An energy tax of 10 US$ per barrel implies an increase of the energy price paid by private consumers of about 7% and that paid by producers of about 20%. The large difference between the per-cent increases arises from the large difference between the energy tax presently paid by the private consumers and that paid by the producers. The revenue from the tax is about 10 billion DKK or about 1% of the gross domestic product.

The major direct macro-economic effects of the energy tax are an inflationary effect due to the increased costs of energy and an income effect due to the revenue of the tax. In the short run the inflation created by the tax is about 2%, increasing to about 3% during the first couple of years; however, in the longer run the inflationary effect is reduced due to an increase in unemployment. The major effects on the real economy are a reduction in private consumption of about 1.5% due to the decrease in real disposable income, a decrease in exports of about 1% due to a decrease in Danish competitiveness, and thereby a reduction of the gross domestic product of about 1%. Energy consumption and CO_2 emissions are reduced by about 6%.

By using the revenue of the energy tax to compensate either private consumers or producers, some of the negative macro-economic effects of the tax may be at least partly offset.

Three ways of using the revenue of the energy tax to compensate the private consumers and producers were analysed, namely, using the revenue to reduce the direct, the indirect taxes, and the labour costs of firms. The different ways of compensation have quite different effects on macro-economic variables like inflation, employment and production. However, in general it is possible to obtain CO_2 reductions with only limited negative effects on economic development. For example, combining the energy tax and a compensation via the indirect taxes the analyses show that it is possible to obtain a 5% reduction in the CO_2 emissions with practically no inflationary effect and only a minor reduction in the gross domestic product. However, in order to reduce CO_2 emission by 5% the energy tax has to be fairly large. Further, in order to obtain much greater CO_2 reductions the energy tax has to be extremely large, and this requires that the tax structure undergoes major changes as the revenue has to be used as compensation in order to reduce the negative macro-economic effects.

4.3 The EFOM Model

The energy system in the Energy Flow Optimization Model (EFOM) is described as a network combining the extraction of primary fuels, through a number of conversion and transport technologies, with the demand for energy services or energy-consuming materials. The system is optimized by linear programming using minimum discounted costs over a long-term period as the objective function, constrained by a number of infrastructural and policy parameters.

In 1991 work has continued on software consolidation and portability, the results of the studies under the CEC JOULE Energy Research Programme have been further analysed and documented, and a new application of the model is being developed for the study on electricity conservation vs. new capacities for the Nordic Council of Ministers (see section 4.10).

The software of the Energy Flow Optimization Model (EFOM) was originally developed in the mid-1970s and has been used for a wide range of studies in various mainframe environments. In recent years the model has been used mainly for studies with environmental constraints. Users within the »EFOM network« and the CEC DG XII have developed new versions of the software for more modern mainframes, workstations and large PCs. The collaboration with the Risø Computer Section and CEC DG XII on the software development continued in 1991, and a portable version of FORTRAN software was finished. The model software is now available for several computer systems, including 386-based PCs, and a combination of a PC user interface and a remote submit via network to large mainframes for solving large problems more quickly. The LIN-PROG linear programming code developed by the Risø Computer Section has been improved by a reduce facility which speeds up computing by a factor of about 2.

The EFOM model belongs to the »bottom-up« approach for techno-economic modelling of the development of the energy system; the complementary »top-down« approach lying within the tradition of econometric models,. e.g. the HERMES model.

The following example shows some details of model results for the Danish electricity generating system with CHP. The model structure and scenario assumptions were specified for the study on »A CO_2 constrained policy« under the JOULE Energy Research Programme.

Figure 4.2 shows the main results of the runs of the model for the Danish power system of one scenario without constraints on CO_2 emissions and a set of others where these emissisons are constrained.

Although energy demand is increasing, the optimization shows that a scenario without CO_2 constraints gives CO_2 emissions that will remain constant at the 1988 level. This occurs mainly because of the imposition of cost-efficient energy conservation, the penetration of new, more efficient technologies and the substitution of natural gas for coal. Scenarios with CO_2 reduction constraints at 10-40% above the 1988 level are characterized by further energy conservation, penetration of natural gas for electricity generation and use of renewables. Tighter CO_2 reduction targets will require that the use of natural gas and CHP be reduced and replaced by relatively expensive non-fossil fuel technologies. This will lead to substantial changes in the model results for the investment pattern from 2000, in particular the penetration of expensive renewable electricity-generation technologies.

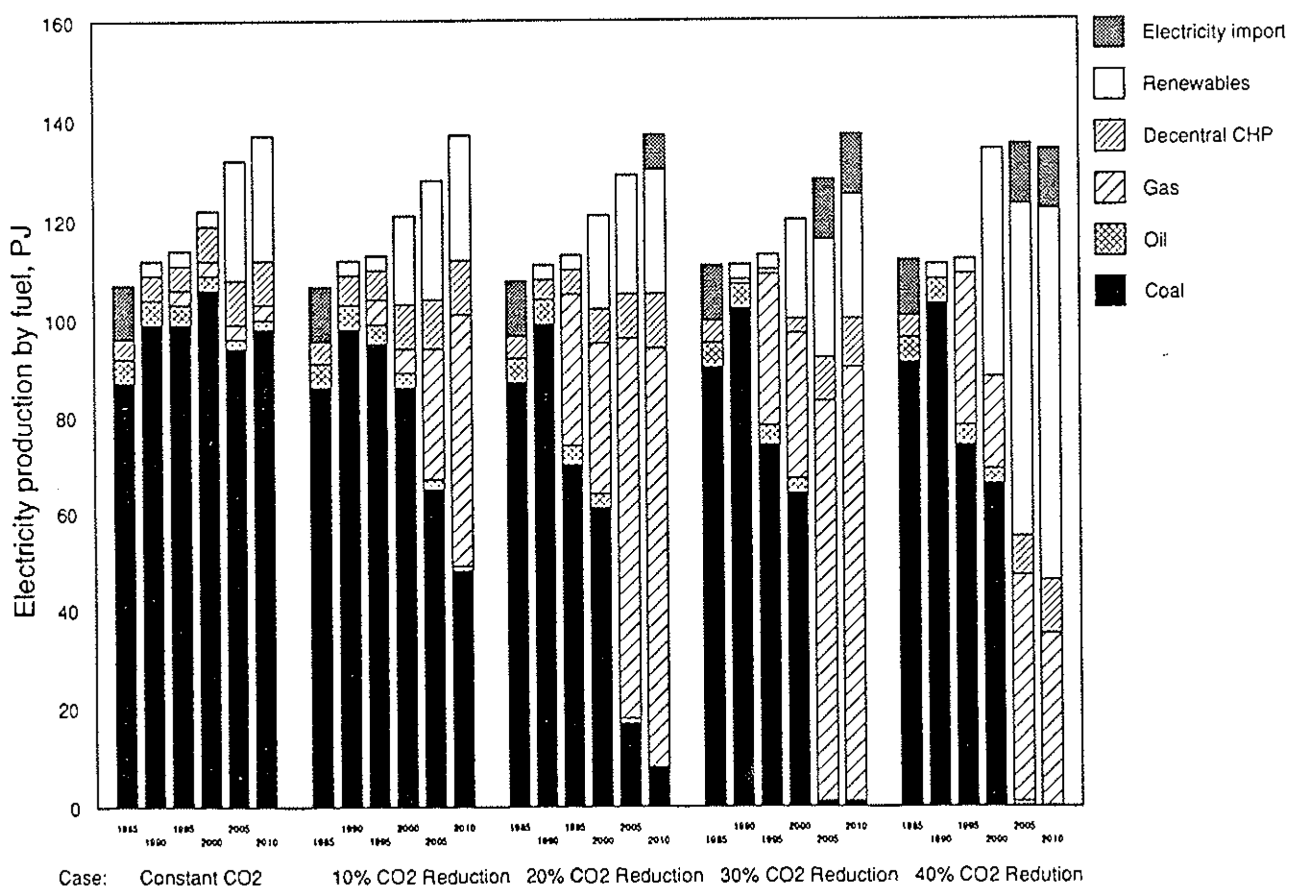
The optimum structure of the system is found by minimizing the total discounted costs over a 25-year period using a standard linear programming solver. Such a result may not be feasible in the real world, because the discounted costs over a long period provide only a very rough measure of economic viability.

Publication in 1991: 83.

4.4 Forecasting Model for the Service Sector

In 1991 a project was initiated to develop a forecast model for electricity demand in the service sector. The project is carried out for the Danish

Figure 4.2. Scenario results for the Danish power system.



Ministry of Energy.

The model includes modules for wholesale and retail trade, private service and entertainment and public services comprising health, education and public utilities for energy and water. It is developed as a simulation model, including econometric as well as technical-economically determined relations.

In recent years the service sector has been one of the fastest growing sectors in Denmark; in 1990 it was responsible for slightly more than one-third of the total electricity demand in Denmark, or approximately 9.5 TWh. Figure 4.3 shows the development in electricity consumption in the service sector (left axis) and the corresponding development in production (right axis).

In the project techno-economic analyses are carried out for the service sector subdivided into a number of branches. Economic analyses are performed for four main branches:

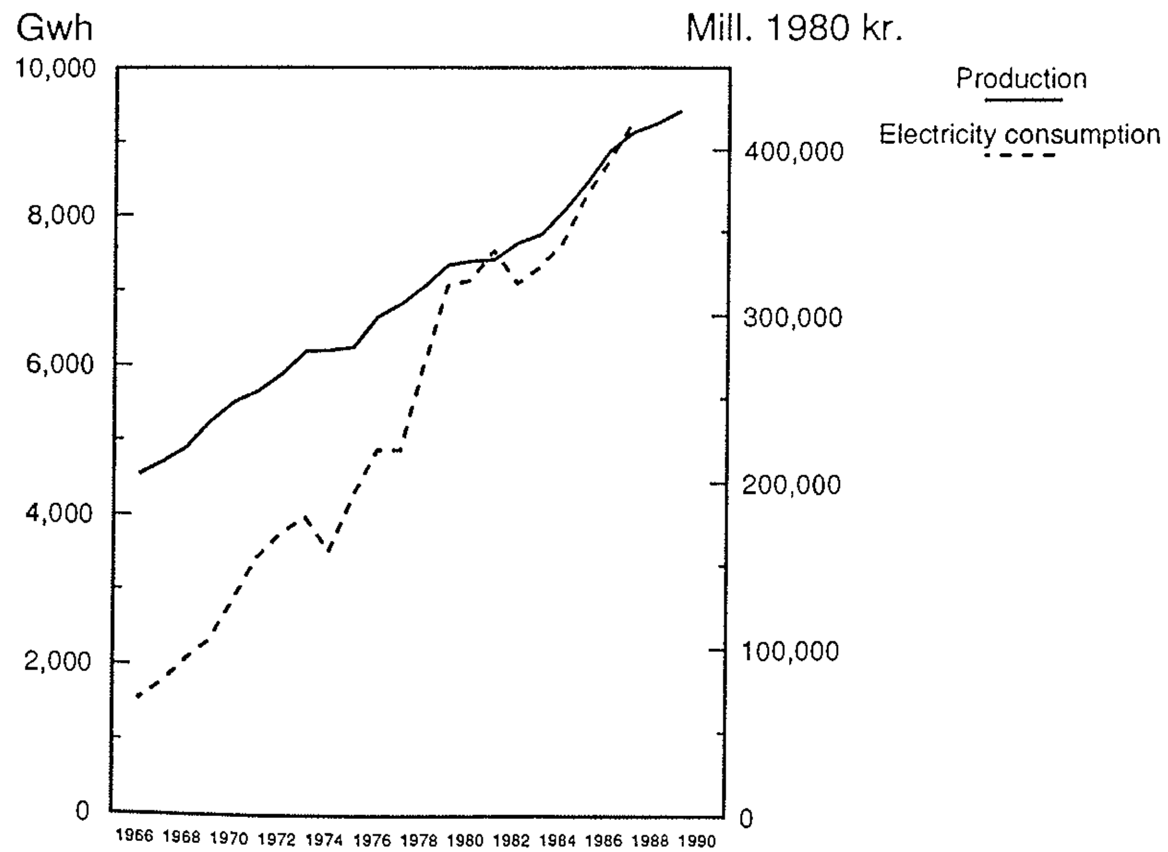
- retail trade,
- wholesale,
- private services and
- public services.

Each of these sectors are analysed using econometric methods, relating relevant variables to electricity consumption.

Moreover, a technical description of each sector is worked out partly as background for the econometric analysis and partly to further split privateand public services into subsectors. These subsectors will be modelled using simulation techniques.

At the close of 1991 the main effort has been concentrated on the econometric analysis and technical description of wholesale and retail trade. The project will be finished at the end of 1992.

Figure 4.3. Development of electricity consumption and production in the service sector.



4.5 Integrated Environmental Models and Uncertainty

A Ph.D. project initiated in spring 1990 was continued. General aspects and characteristics of integrated environmental models have been studied, focusing on models with policy-making objective. Not many models are actually used to support decision making. Two dimensions of this problem can be identified: the model and its perception (questions about robustness, accuracy, uncertainty, scepticism towards models, etc.) and the complexity of the decision-making environment (conflicts of interest between the interested parties, time pressure, etc.).

Different kinds of uncertainties influence the above-mentioned problem. Making a decision implies in theory three steps: a) identifying and structuring the problem to be addressed, b) describing the problem (for example, modelling) and c) going through the decision-making process itself. A large number of methodologies exist to characterize and deal with uncertainties. They vary greatly in mathematical and analytical approaches and it can be a task in itself to find the appropriate methodology to use. In general, most technologies are used after developing the integrated models and for setting up single submodels in the model structure, and performing the calculations leaving out evaluations of the integrated model as a whole. Not much attention is given to the uncertainty aspects present in the decision-making process.

In 1991, the focus has been on two selected case studies which are to illustrate general theoretical aspects in integrated environmental modelling and decision making.

The first has analysed the decision-making process which resulted in the Danish Water Action Plan. The process was influenced heavily by a poorly defined and structured problem, and by uncertainties in the calculations and scientific knowledge. The case illustrated the complexity in practical decision making, and draws up a picture of the difficulties encountered in developing a model which can provide actual support in such a complicated situation. The outcome of the study was a suggestion for an alternative, more methodological approach for the planning and decision-making process. This approach is based on modern planning principles where the focus is on cooperation, participation, acceptance of alternative viewpoints, analysis of a number of different strategies, and definition of different decision sets (in contrast to one overall decision). Hereby, uncertainties and complexities are acknowledged and can be dealt with by introducing aspects of robustness and flexibility into the planning and decision making-process.

The second case study was made during a 9-month stay at IIASA. The aim here was to get an overview over general theoretical aspects of the treatment of uncertainty in integrated models and their use by studying the RAINS model. Furthermore, it was decided to make a sensitivity study of a part of the RAINS model. This study focused on sensitivities of estimates and curves to input parameter values, all of which are a result of cost calculations in the model. These estimates and curves are of main concern for the decision makers. The study was at the same time an example, of how to make a sensitivity test in a generally consistent way for an integrated model. The study showed that two parameters in particular (sulphur content of the fuel and the capacity utilization of power plants) have an impact on the cost calculations, i.e. cost curves as well as results obtained by the optimization framework.

In 1992, work will focus on a practical real-life problem, e.g. modelling CO_2 reductions in a developing country.

4.6 Emission Inventories

In 1991 the group continued its activities in the field of quantification and assessment of emissions to the atmosphere, particularly from the energy system. The work about the Danish budget for greenhouse gases was carried out in collaboration with the National Environmental Research Institute. It was initiated and partly financed by the Ozone and Climate Committee of the Nordic Council of Ministers, with ESG's contribution being financed by the National Agency of Environmental Protection. The resulting emissions from Denmark for 1989 are shown in Table 4.1. Most of the emission of CO_2 (50.7 million tons) comes from the energy sector. If imported electricity was to be produced with current fossil fuels, the emission would have been 8.6 million tons higher in 1989.

A study of the emissions of volatile organic compounds (VOC) from Denmark was carried out in collaboration with dk-TEKNIK. The study was carried out for and financed by the National Agency of Environmental Protection.

The emission inventories for SO_2, NO_x, CO_2, CO, N_2O, CH_4 and NMVOC for Denmark were also reported in 1991 to the National Agency of Environmental Protection, who in 1992 has financed a similar project. The calculation of emissions from the traffic sector was coordinated with CEC-COPERT model and the model at the Laboratory of Energetics at the Technical University of Denmark.

Table 4.1. The main primary greenhouse gases and the present Danish contribution from various sectors to the global emission. Unit: 1000 tons per year. Best estimates for 1989.

Sector	CO_2	CH_4	N_2O	CFC-11	CFC-12
Power plants	20704	0.06	0.66		
Coal storage		16.00			
District heating	4315	0.01	0.13		
Process (energy use)	10160	0.07	0.38		
Individual heating	7683	1.78	0.29		
Domestic transport	10223	6.93	4.28		
Use of biomass	-2389				
Gas network		8.45			
Industry	917	0.04		1.359	0.450
Landfills		310.00			
Waste water		1.60			
Agriculture (biogenic)	3500	262.00	14.6		
Forestry	-2600	-3.00	0.6		
Natural ecosystems		350.00	4.2		
Total domestic emission	52513	953.94	25.14	1.359	0.450

In 1991 the CORINAIR work continued; this is a programme of the Commission of the European Communities aimed at establishing a database on emissions of atmospheric pollutants in all the member states. Atmospheric emissions are transboundary in nature and a common, transparent, and coherent set of data for the European nations is essential for qualified evaluation of the origin, transport and deposition of pollutants.

The CORINAIR programme will be continued and expanded during the next few years and will eventually be monitored by the European Environmental agency.

The coordination of European emission inventories has been dramatically improved. In July 1991 a complete agreement between UN/ECE and CEC/CORINAIR was achieved. The great advantage of this agreement is that countries who join the CORINAIR methodology have also fulfilled their obligation to EMEP as members of UN. This encourages non-EC countries to participate in CORINAIR-90, which was started in September 1991. ESG will be responsible for the Danish inventory and will assist the three Baltic countries in making their inventories.

A new EUROTRAC subproject called GENEMIS (Generation of European Emission Data for Episodes) was accepted. GENEMIS will take full advantage of the CORINAIR inventory but will be much more detailed with respect to temporal resolution and to VOC specification. ESG will participate in GENEMIS with two projects, one for the Danish land area and another for European emissions from the sea and from air traffic.

Publications in 1991: 13 and 14.

4.7 Hydrogen as an Energy Carrier

The project dealing with hydrogen as an energy carrier was initiated in January 1991. The project was financed by the Danish Ministry of Energy and by the Danish public utilities ELSAM and ELKRAFT. The aims of the project were to gather and disseminate the research which has been going on around the world until now concerning hydrogen and assess the perspectives for producing hydrogen and utilizing hydrogen as an energy carrier in the Danish energy system.

A special interest for the Danish public utilities has been the possibility for utilizing hydrogen as a storage medium for electricity. For that reason a first part of the project has been a study of this utilization including the energetic and economic consequences. The study has been based on literature surveys and interviews.

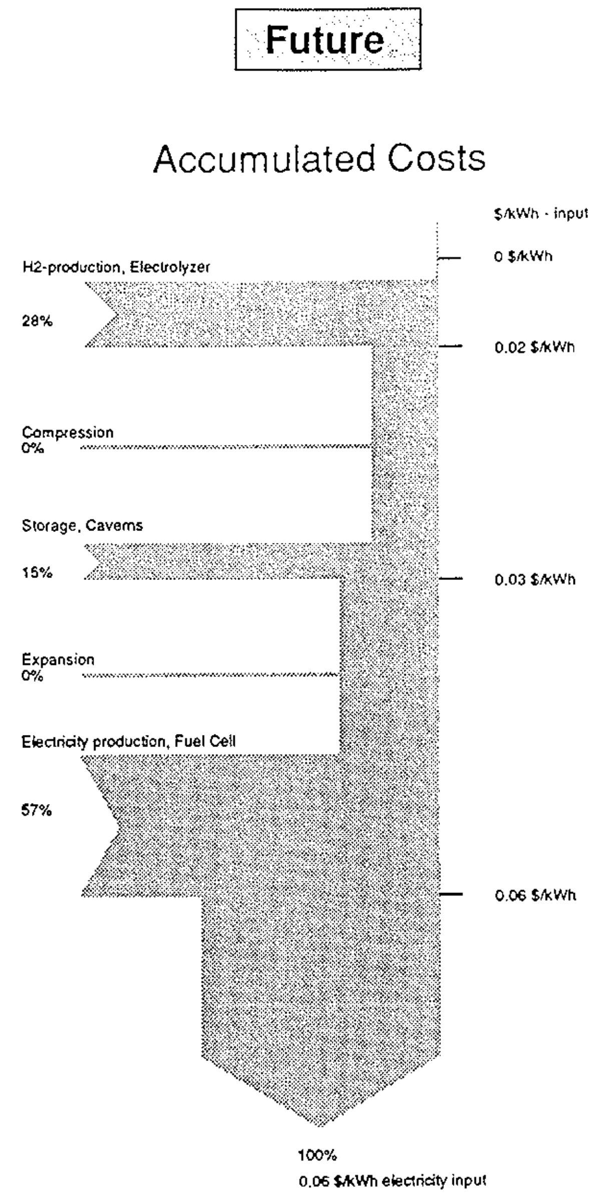


Figure 4.4. Accumulated costs per kWh electricity delivered to the storage system.

The system which has been analyzed for electricity storage based on hydrogen consists of an electrolyzer, a hydrogen store and fuel cell. The electrolyzer produces hydrogen (and oxygen) based on electricity. Hereafter the hydrogen is compressed, cooled, and led to the hydrogen store.

The store was intended only as a seasonal store. As the amount of hydrogen stored in this case will be large, the store chosen for hydrogen storage is a cavern in a saltdome. After the period of storage hydrogen is recovered from the store, expanded and converted to electricity and heat in fuel cells, whereby the storage cycle is closed.

Although the store has been dimensioned for one year, the store can be used for smaller cycles too, for instance as a day and night store.

The efficiency of the system working only as an electricity store is expected to be close to 60% in the future (about 2015). Of the incoming amount of electricity to the system 35% is expected to be usable for heating purposes. By producing power as well as heat the total efficiency of the system will be 94%.

By placing the electrolyzer and the fuel cell close to a district heating system the loss of energy thereby seems very small if hydrogen is used as an energy carrier.

The estimated extra costs of using hydrogen as an electricity store are shown in Figure 4.4, expressed as $/kWh electricity entering the storage system. The costs include investments, operation and maintenance, but do not include the cost of input electricity to the system. Therefore costs of energy inputs must be added. Furthermore, the value of the related heat and oxygen produced should be subtracted.

Based on the figure and the efficiencies mentioned the electricity energy costs of drawing 1 kWh from the seasonal store at those times of the year when the demand of electricity is large appears to be about 0.10 US$/kWh.

The possible advantages in the total CHP system which may appear by combining it with an electricity storage facility based on hydrogen have not yet been considered. For example, it is expected that an electricity storage system can substitute for power installed elsewhere in the system.

In the next step of the project alternatives for hydrogen production will be considered depending on how the hydrogen will be introduced to the energy system. The work will continue in 1992.

Publications in 1991: 65, 66 and 68.

4.8 The European Internal Energy Market and Nordic Energy Policy

During 1991 the Energy Market Group of the Nordic Council of Ministers financed a project on the consequences for energy policy in the Nordic countries of the EC internal market for energy; the problems or opportunities for utilities and regulators in the Nordic countries were

also considered. The legal framework for the internal market is the transit directive for electricity and natural gas, which was adopted by the Council in spring 1991 and went in to effect in July 1991 for electricity and January 1992 for natural gas.

The study was undertaken in collaboration with Scan-Energy ApS. A series of interviews was carried out with executives in the gas and electricity sector in the Nordic countries. A preliminary report was represented at a seminar in November hosted by the Nordic Centre for Environment and Society. The final report will be finished early in 1992. One of the main conclusions of the study is that a substantial export of hydro-based Scandinavian electricity will contribute to international environmental targets that are supported in particular by the Nordic countries. At the same time there is a potential for large export revenues.

Figure 4.5. Existing and potential electricity and gas transmission lines in the Nordic region.

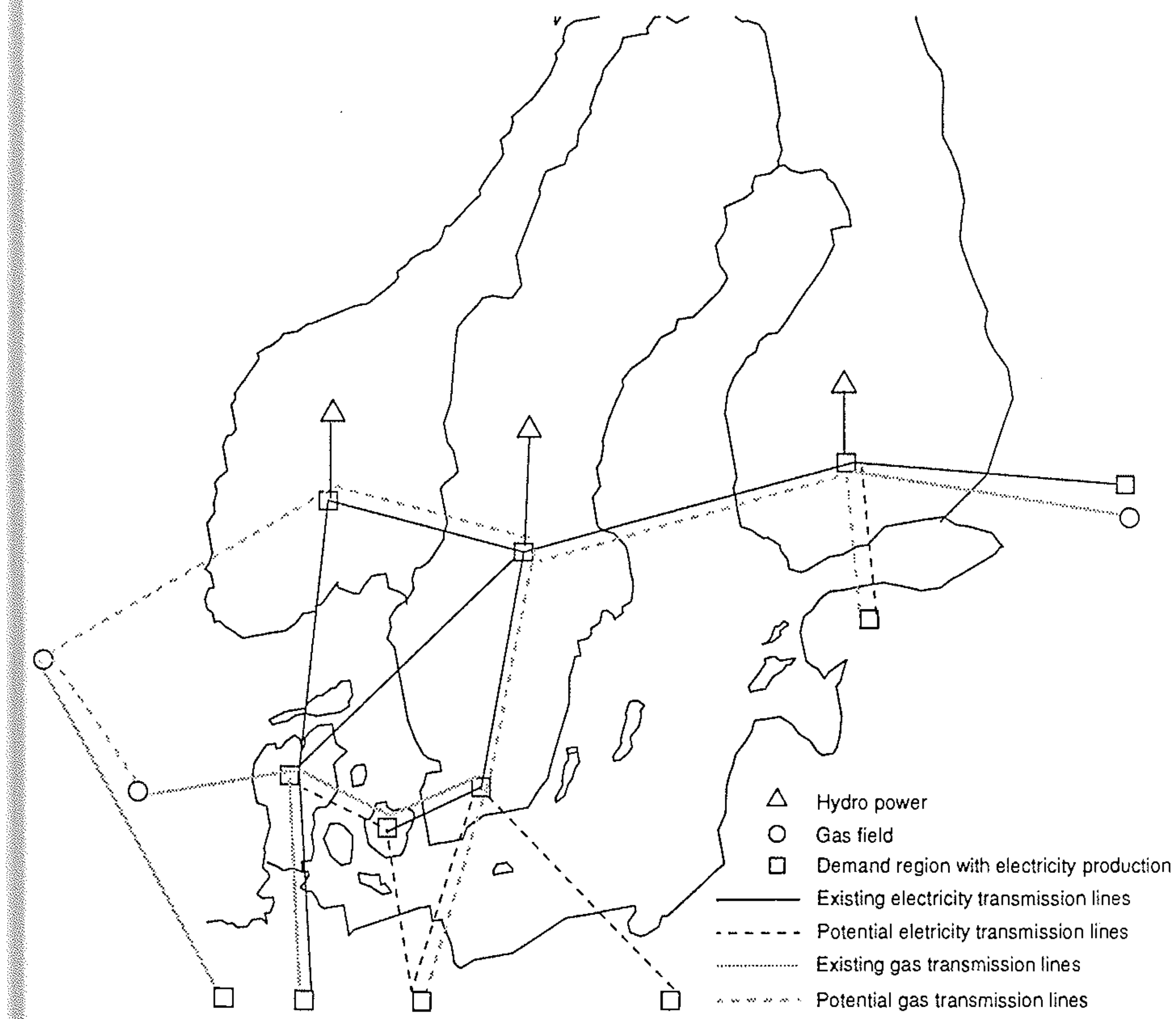


Figure 4.5 shows the existing and potential electricity and gas transmission lines from the natural resources of hydropower and natural gas to the demand regions. Thermal electricity generation does not necessarily compete with imported power.

In Norway, Sweden and Finland there is a development towards a more commercial attitude in the electricity sector in the direction of a system of third party access, while the regulation of both markets is still very important in Denmark. The EC transit directive will be the legal framework for operating the new transmission lines that are now under construction or planned. Although the transit directive may lead to lower electricity prices in most of Europe, higher prices may be expected in Scandinavia, because the cheap hydropower will have access to European markets that currently are subject to higher prices.

4.9 Energy Planning in Eastern Europe

The countries in Eastern Europe and the former Soviet Union face the huge task of reshaping their economies so that they can compete and grow but at the same time reduce pollution. The inefficient use of fossil fuels has been the primary cause of pollution. Instead of encouraging a raising energy consumption, energy efficiency has to be the primary goal in energy policy.

The focus of the work in this field was in 1991 on the countries around the Baltic Sea. In the project »Baltic-Nordic cooperation in the field of energy and environment« for the Energy Market Group under the Nordic Council of Ministers, the report »Energy and Environment in Estonia, Latvia and Lithuania« was published in August 1991.

Estonia has roughly the same area as Denmark, but Latvia and Lithuania are about 50% larger (Table 4.2).

The population density is much lower in the Baltic states than in Denmark. The area covered by their forests (28-42%) is much larger than in Denmark (11%), so that as in Sweden and Finland wood is an important energy resource. The potential for wind energy is good in western and northern Estonia and along the Latvian coast. Geothermal energy is a possibility in western Lithuania and in south-western Latvia. The only domestic fossil fuel resource being used is Estonian oil-shale which is the main fuel for electricity production in that country (Table 4.3). This activity has created a severe ecological damaging situation in north-eastern Estonia with large emissions of SO_2 and other substances and with deterioration of land and water resources by the extraction of shale and disposal of large amounts of ash in dumps.

Table 4.2. Area and population.

	Estonia	Latvia	Lithuania	Denmark
Area (mill.km^2)	45.1	64.6	65.2	43.0
Population (mill.)	1.6	2.7	3.7	5.1
Population density (cap./km^2)	34.9	40.8	56.7	118.9

Latvia produces only half of the electricity needed, mainly by the three big hydropower plants on the Daugava river. In Lithuania the power comes from the Chernobyl-like Ignalina power plants and oil-fired power plants. In all three countries there is a large potential for energy conservation, as to be shown in a forthcoming report.

In 1991 the town of Gliwice in southern Poland was the site of an energy planning project, a joint venture of Rambøll & Hannemann A/S, Roskilde University Centre, the County of Storstrøm and Municipality of Gliwice. The work was funded by the Danish Interministerial Committee for Central and Eastern Europe (IMØ) and the Commission of the European Communities (DG XVII). The objective was to create a basis for making decisions by the Municipality and by energy supply companies in Gliwice about initiatives for establishing a robust, economic and environmentally sound energy supply for the town. Some preliminary scenarios were made: continuation of the present system, a new CHP-plant, energy savings and supply of surplus heat from industries. The decision tool used was transferred to the municipality.

Publications in 1991: 12, 16 and 17.

Table 4.3. Present installed electric power capacity.

MW	Estonia	Latvia	Lithuania	Denmark
Hydro	0	1487	106	7
Wind	0	0	0	250
Oil	207	473	2646	67
Natural gas	0	140	0	267
Oil-shale	3104	0	0	0
Coal	0	0	0	7752
Nuclear	0	0	2500	0
Total	3311	2100	5252	8343

4.10 Electricity Production Versus Electricity Savings

A project dealing with the investment in electricity savings instead of extended electricity capacity was initiated in 1990, financed by the Nordic Council of Ministers.

In the project a model has been developed that considers the correlation between electricity savings and a future electricity supply. Thereby it is possible to investigate how much one may invest in savings as an alternative to adding to the present supply.

The aim of the project is to demonstrate the model for each of the Nordic countries, as the electricity supply varies considerably from one country to another. The project will be completed in 1992.

Publication in 1991: 67.

4.11 Economic Assessment of Joint Biogas Plants

In 1986 the Danish Ministry of Energy set up the Coordinating Committee for Joint Biogas Plants, the main objective of which was to prepare and coordinate a Plan of Action for such plants; the plan was formulated during 1988-90.

Following this plan a number of biogas demonstration plants were established. In 1991 an assessment of the social economics of three of these plants: Davinde, Fangel and Lintrup has been carried out in collaboration with the Institute of Agricultural Economics. To facilitate the calculations a biogas-economic model was developed, including the energy and environmental as well as agricultural aspects of establishing biogas plants.

Joint biogas plants are not merely energy-producing, but have a substantial impact upon the environment in general as well as agriculture in the following ways:

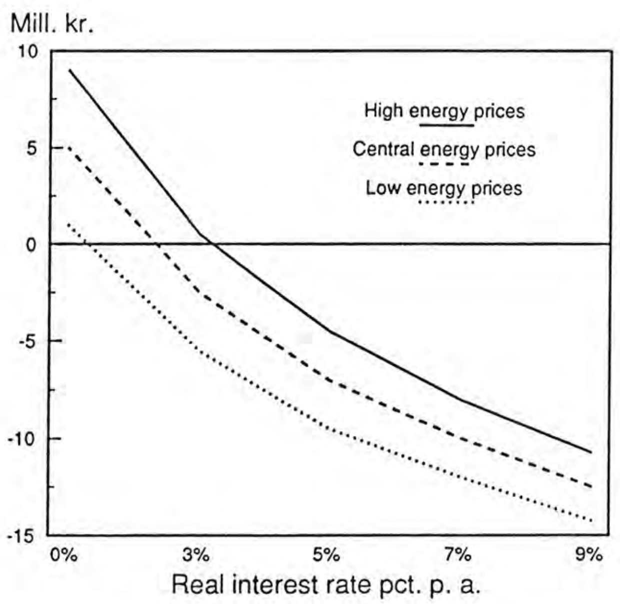
- the use of manure as fuel makes the biogas plants neutral with respect to the emission of carbon dioxide,
- the use of industrial refuse as manure after treatment by the biogas plants reduces the need for waste disposal, and
- the storage facilities established at the joint biogas plants make it possible for the farmers to reduce on-site storage and provide an opportunity to utilize the manure in an optimal way.

The economic calculations show that at their present state of development joint biogas plants are not competitive with traditional energy-producing plants. This is partly because these plants still are to be considered pilot plants; for this reason investment costs as well as those of operation and maintenance are higher than they would be in the future.

A comparison of the joint biogas plant in Fangel with a corresponding conventional energy-producing plant enables the difference in net present value to be calculated. Figure 4.6 shows this result, including that of a sentivity analysis on energy prices and the real interest rate. The base case is calculated using the central energy price development, and an interest rate of 7% p.a. in real terms. Essentially, the calculations for Davinde and Lintrup give the same picture.

Emissions of both CO_2 and SO_2 are favourably influenced by the establishment of biogas plants, while NO_x emissions are decreased to only a minor extent. The above-mentioned results do not include an economic assessment of emissions. If emissions of CO_2, SO_2 and NO_x are eva-

Figure 4.6. Comparing the net present value of a biogas plant to a conventional energy-producing plant.



luated at their marginal system costs, the economic results are at best close to break-even.

Publication in 1991: 28.

4.12 Economics of Privately Owned Windturbines in Denmark

According to the latest Danish energy plan »Energy 2000« the capacity of wind turbines connected to the main electricity grid is expected to increase from 350 MW in 1991 to 1500 MW by 2005. This means, that the share of wind-generated electricity of the total electricity production will increase from approximately 3% today to approximately 10% in 2005.

On behalf of the Danish Energy Agency a project on the economics of privately owned wind turbines has been carried out in 1991, taking into account the different conditions of taxing, financing and organisation of the wind turbines. Moreover, the calculations took into account the statistical variations in important input data, such as investment costs, electricity production from the turbine, and operation and maintenance costs.

Figure 4.7 below shows the distribution of the net present value of a 150-kW wind turbine, commonly owned (i.e. share by several persons). Given an investment cost of 1.3 million DKK on average, the average net present value will be approximately 700,000 DKK, corresponding to a net rate of return of 6% p.a. Especially due to statistical variations in the turbines' electricity production the variation in results is substantial. Thus, the lower 5% of the turbines will have a negative net present value, while the upper 5% will have a net present value of more than 1.7 million DKK.

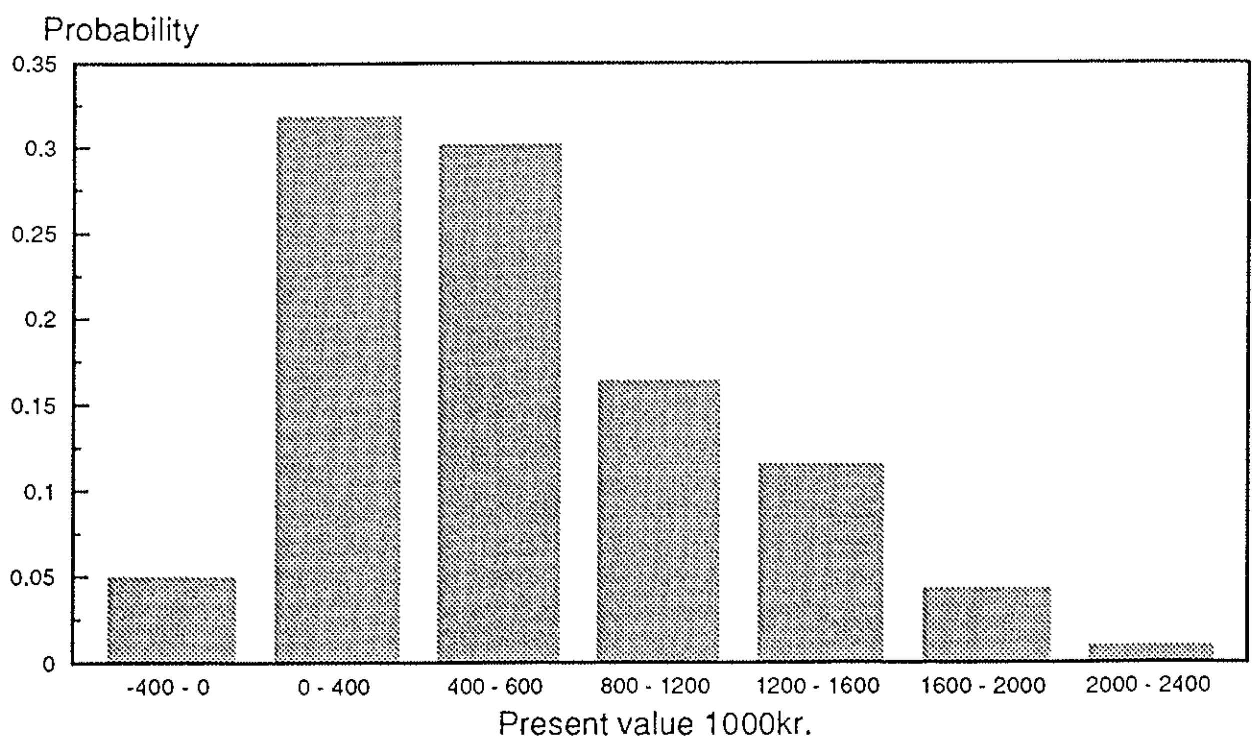
On comparing a corporate-owned-turbine with a single-person-owned machine a significantly reduced profitability is found in the latter case. This is due to a combination of several factors:

- the tax rules are less favourable for single-person-owned turbines,
- there is no refund of VAT on the electricity tax, only the tax itself is refunded, and
- other conditions for borrowing.

The net rate of return for a single-person-owned turbine is close to 0% p.a.

Publications in 1991: 53 and 54.

Figure 4.7. Distribution of net present value of a 150-kW wind turbine.



4.13 International Conventions Concerning the Environment

In 1991 a Ph.D. project »Guidelines in international conventions concerning the environment - greenhouse gases and climate-agreements« has been initiated. There has recently been a growing concern about the greenhouse effect and an acknowledgement of the need for international cooperation in the form of agreements and conventions.

The aim of the project is to analyse different possible international agreements aimed at limiting emissions of greenhouse gases, particularly carbon dioxide.

For regional environmental problems such as acid rain it has been shown that there are considerable benefits to be gained by cooperation between countries. In a full cooperative solution which allows for side payments, the average benefit will be about twice that of the case of a uniform reduction due to the different distribution of emission reductions which takes place when differences in reductions costs and deposition damages between countries are taken into consideration.

Global externalities are very similar to regional ones from an economic analytical point of view. However, the global environmental problems (e.g. climate changes) depend only on worldwide aggregate emissions of climate gases and not on how these are distributed among countries. Unlike acid rain where a considerable part of a country's emissions fall as a deposition within its borders, a country has less interest in reducing those emissions that affect the global environment, and so it is less motivated to curtail them. Therefore, solutions to global environmental problems of this kind require international cooperation to the greatest extent. The motive for signing a convention is that the other signatories commit themselves to reduce their emissions as well. Part of the project will be to find solutions to minimize the problem of countries gaining an advantage by doing little or nothing.

Due to the inefficiency in an agreement where all participating countries reduce their emissions by the same (relative) amount two alternative types of agreements will be analysed: a) an international greenhouse gas tax, and b) tradeable greenhouse gas emission permits. These types of agreements may give an outcome which is very close to a first best social optimum.

Considering the disparate costs and benefits and the disparate technical and economical conditions in the various countries, it will be analysed:

- which incentives the countries will have in participating in an international agreement and
- how the costs and benefits can be allocated, i.e. the possibility of equitable sharing.

This part of the project will include calculations on different allocations in accordance with objective criteria such as GHG emissions, population, and GDP.

A crucial point in getting a cost-efficient and equitable solution is knowledge about the greenhouse gas abatement cost functions in the different countries. The UNEP-project on establishing a set of methodological guidelines for calculating the potential for, and costs of, limiting greenhouse gas emissions (see section 5.5) will therefore be used to find the optimal solution of a convention.

4.14 Energy Planning for the Cape Verde Islands

During 1991 the project which has been commissioned by Danida continued, in which technical assistance was given to the Ministry of Industry and Energy, Cape Verde.

In Cape Verde 1991 was unique in that the first election took place in which two parties participated, resulting in a change of the ruling party from a Marxist-oriented to a democratic one. This, however, influenced the project in that no important decisions were made and no planning took place before the new government had published its programme in August 1991. Because of this the Danish adviser concentrated on a review of some ongoing and completed projects related to energy, and also on a preliminary study of possibilities for introducing wind power in small electrical grids. This choice was made in accordance with the desires of the local administration.

A number of energy-related projects were studied, some being established 5-10 years ago mainly for power and/or water supply. Some were performing well, other needed funds for maintenance, and a few were abandoned even before the projects were terminated in an orderly manner.

The general impression is that in many cases the hardware has not been adapted sufficiently to the physical and economic environments.

Presently, electricity is produced mainly by diesel power and is confined to a limited part of the country only, mostly the larger cities and villages. Connections between power stations on a given island are seldom made, which means that the costs of production are high because of the small units (50-200 kW) and expensive diesel oil used. Consequently, the possibilities for implementing wind-generated power in the small grids were studied in order to get preliminary data that would serve as a base for estimating which sites may be candidates for a more profound study of wind properties, load characteristics, future demand, etc. In the project period all islands were visited. The local administrations were interviewed about current and future consumption, projects concerning energy-demanding industries, and current production prices. In most cases it was very difficult to get specific information, especially of an economic character. The power stations were then visited to get data on the equipment, oil consumption, and the production profile. Often the data were very inaccurate or even non-existent because the devices for measuring energy production were out of order or the oil consumption was either given in a phrase like »usually three barrels per week« or was simply unknown. Finally, the surroundings were examined in order to estimate the possibilities for siting a wind turbine in the relative free flow of the trade wind at an accessible site not too far from the existing grid.

The data collected at the visits are described in a report which will be completed in the beginning of 1992. It contains a preliminary evaluation of the load characteristics and existing, sparse measurements of wind properties; it also points out some sites which may be subject to further detailed studies. If an agreement is reached to carry on with an extension of this project, the goal will be to propose the installation of wind turbines in certain locations where the economic results are found to be feasible.

These future studies may comprise measurements of wind properties, more detailed studies of the present and future demand for electricity, and, finally, an estimate of the economic consequences of implementing wind power in the selected power systems.

4.15 Wind Energy Planning in Egypt

As a result of the findings of an early 1990 feasibility study on utilising wind energy in Egypt, a project was formulated for demonstrating and developing technology and planning in the wind energy sector in Egypt. An immediate action programme was put into operation in 1990 and was continued in 1991.

This immediate action programme involves several different units at Risø. ESG is responsible for the planning component, containing institutional support for preparing a master plan for large-scale introduction of wind energy in Egypt.

Most of that part of the work on the programme which dealt with the master planning component took place in 1990. In 1991 one session has taken place in Egypt. The main purpose of the mission was to prepare a plan of operation for going on with the project. During 1991 the activities were concentrated on continuing the planning work, and were expected to be initiated in 1992 and last three years.

4.16 Sewage Treatment Plant

In 1988 a project was initiated in collaboration with I. Krüger AS, financed under the Danish Energy Research Programme 1988 (EFP88). The aim of this project is to analyse the energy-related aspects in sewage treatment plants with a view to increasing plant performance during winter.

In order to analyse the problems during winter operation, a detailed investigation of the operating conditions has been carried out. During the past winters temperature data in different basins have been collected for two sewage plants by datalogging, and they have been used for demonstrating a model that describes temperature drops.

Existing models for calculating the net heat loss from a sewage treatment plant are all based on steady-state conditions and mean temperatures during a month, but for the rapid changes in temperatures that occur in the northern part of Europe a dynamic model is necessary. Therefore, in 1991 a model has been developed giving a dynamic picture during one to four weeks of the changes that take place in temperatures over intervals of one to six hours.

The predicted temperatures using the dynamic model are very close to the measured values, when the velocity of the wind is low, but for large wind velocities the predicted temperature drop becomes larger than registered. Therefore, the dynamic model will include improved modelling of wind conditions, and local climatic measurements will be collected at the plants involved. By use of the model it is possible to assess the importance of the construction and operation of the plants, and determine whether one type of sewage treatment plants is better than the others.

5 UNEP Collaborating Centre on Energy and Environment

The UNEP Collaborating Centre on Energy and Environment operates under an agreement between the United Nations Environment Programme (UNEP), the Danish International Development Agency (Danida), and Risø, provisionally for a four-year period from October 1990. The main objective of the Centre is to promote and facilitate the incorporation of environmental aspects into energy planning and policy both at the national level in developing countries and in UN agencies and other international organisations.

The activities of the Centre are concentrated under the following four headings:

* Assessment of environmental impacts from energy production and use.
* Energy-environment policy studies in selected countries.
* Information centre on energy-related environmental effects, energy planning methods, and models.
* Scientific and technical support to UNEP on energy questions on an ad hoc basis.

The Centre was officially inaugurated on 11 February 1991 and the staff has gradually been expanded through the year to become an international multidisciplinary team of 5 full-time professionals by the end of 1991.

In addition to the core activities the Centre is engaged in a limited number of projects financed by different international organisations. This type of engagement is encouraged by the three founding organisations and is expected to increase in the coming years.

During the year the Centre published two issues of the newsletter C_2E_2 News, containing information on Centre activities and related topics. The newsletter is distributed worldwide and has already received considerable positive response.

5.1 Environmental Database (EDB)

One of the main overall aims of the centre is to promote environmentally conscious energy planning in developing countries. An important component of this effort is the development and dissemination of planning tools which make it possible to assess the environmental implications of different energy alternatives.

Assessment of the full environmental consequences of energy production and use involves detailed calculations of emissions of pollutants, their transport through the air and water, and the deposition of pollutants with consequent ecological and health damage. These require detailed site-specific information as well as meteorological modelling and data on ecosystems, none of which is commonly available in developing countries at present. Often however, alternatives can be judged on the basis of the emissions alone. Thus a database of emissions and similar direct effects, which may be termed »the environmental loading«, can have general validity for different locations. The database can subsequently provide a basis for more detailed site-specific studies.

The Environmental Database (EDB) was developed by the Stockholm Environment Institute's Boston Centre (SEI-B) with partial funding from UNEP. The purpose of the database is twofold. It can be used in conjunction with the energy planning model LEAP (also a SEI-B development) to calculate the environmental loading of any energy scenario. The database can also be used as a »stand-alone« reference tool to provide appropriate data on the environmental impact, e.g. emissions, of particular energy technologies.

The Centre operates EDB on behalf of UNEP and in 1991 the Centre and SEI-B agreed formally to be joint hosts for EDB. The Centre and SEI-B thus share the responsibility for developing, maintaining, and disseminating EDB. SEI-B is responsible for software development and maintenance, while the Centre is in charge of data content and dissemination of the database to institutions in developing countries.

The database contains quantitative information on emissions and similar direct effects associated with a wide range of energy production and consumption technologies, in particular the emission of gases. Work is continuing at the Centre and at SEI-B to extend the coverage and applicability of the database.

During 1991 EDB was installed in Ecuador, Tanzania, Costa Rica and Senegal, and there are plans to make the database available in all Latin American countries through cooperation with OLADE.

Work is continuing on expanding the coverage of the database by including specific data obtained in the host countries and from other sources such as the European CORINAIR emission inventory (see section 4.6). The representation of emissions from the transport sector often presents problems because of the diversity of conditions, vehicle standards, journey types and other uncertainties. Some of these problems are addressed in the project on urban transport in India carried out by Ranjan Bose during his stay as guest researcher.

5.2 Energy and Environment in Latin America

Environmental aspects have not as yet played a major role in the formulation of national energy policy in the Latin American and Caribbean (LAC) region. Economic and technological concerns have dominated discussions of the nature and role of energy use and national energy planning.

As in other developing regions in the world, there is a potential conflict between the objective of satisfying basic energy requirements to achieve economic growth and social development, and the need to reduce the environmental damage associated with growing energy consumption. A balance between these conflicting goals must be reached. One way of doing this is to encourage a deeper understanding of the nature and extent of environmental problems among planners and policy makers so that the environmental consequences of alternative energy policies are better understood.

The Centre collaborates with the National Energy Institute (INE) of Ecuador through a pilot project aimed at supporting and enhancing the technical and political awareness needed for developing and promoting a more environmentally sound energy policy. The objective of the first phase of the project is to establish a national environmental database for Ecuador. This involves the transfer and adaptation of the UNEP/SEI-B Environmental Database (EDB) (see section 5.1), compilation of specific national data and incorporation of these data into EDB.

Collaboration with a relatively small country like Ecuador provides an opportunity to develop and test a set of planning tools and guidelines for a widespread use. At the same time it supports and builds on the energy planning process started by INE some years ago. The project is supported by the Commission of the European Communities (DG-I) within the frame of energy planning assistance to developing countries. Members of the Centre took part in a mission to Ecuador during 1991, and early in 1992 INE staff will visit the Centre to collaborate on the database activity.

On a broader scale the Centre has recently developed a joint proposal for a new activity programme with the Latin American Energy Organisation (OLADE) and the Stockholm Environment Institute-Boston Center. The programme aims at incorporating environmental aspects into energy policy and planning at the national level in the Latin American region. The proposed programme focuses on establishing a database on emission sources and broad environmental impacts from energy activities, developing an inventory of present and projected emissions, loads and other environmental impacts, and providing planners from national planning institutions with training, tools and methods that will deepen their analysis capabilities. The Environmental Database (EDB) and the energy planning model LEAP will form the basis of this activity.

With regard to the UNEP Centre, the outputs and experience gained in this collaborative effort will be utilized in other similar activities in other regions or at the sub-regional or national level, and will help to determine the objectives for further enhancing energy-environment planning tools.

5.3 National Greenhouse Costing Studies

In 1991 UNEP launched a major new project aimed at establishing a set of methodological guidelines for calculating the costs of limiting greenhouse gas emissions, particularly carbon dioxide from the energy sector. The project is being coordinated by the Centre, with assistance from Caminus Energy (Cambridge, UK) and the Tata Energy Research Institute (New Delhi, India), and with Dr. Michael Grubb of the Royal Institute of International Affairs (London, UK) as consultant.

Emissions of CO_2 from the energy sector can be limited or reduced by a variety of means, such as energy savings, fuel switching, and introduction of more efficient technologies. Some of these measures may be economically attractive in their own right, so-called »no-regrets« options. However, significant constraints or barriers exist to prevent or hamper the uptake of more energy-efficient plants, equipment, vehicles and buildings. Economic incentives to influence the actions of both energy producers and consumers, on the other hand, may need to be so large that they would have important macroeconomic impacts.

A number of industrialised countries, including Denmark, have undertaken studies to calculate the cost of reducing the emission of greenhouse gases, particularly carbon dioxide. The estimated costs of reduction vary enormously from one country to another, and even from one study to another carried out within a single country. This apparent disagreement among studies forms the background for the present project.

The reasons for disagreement between costing studies can be classified into differences of methodological approach and differences in assumptions. In particular, the methodological differences are characterised by the use of two types of modelling approach: the top-down or macroeconomic approach, and the bottom-up or end-use approach. Each approach is characterised by its own set of assumptions with regard to level of detail, time horizon, as well as terminology such as the definition of cost. In the macroeconomic approach for example, the cost is generally associated with the impact of a particular measure on the gross national product. In the bottom-up approach, on the other hand, cost is generally taken to mean the additional investment and operation and maintenance costs of emission-limiting actions.

National reviews and costing studies will be undertaken for a number of countries which span a range of energy and economic systems and stages of economic development. These national case studies will be carried out by teams in the respective countries, with external assistance where appropriate. The studies will be based as far as possible on common guidelines formulated by the project team.

Following the aim of covering a broad spectrum of countries, a number of government agencies in the industrialised countries were approached with a view to supporting studies in their own countries as well as in developing or formerly centrally planned countries. The following countries are involved in the project so far: Denmark, France, Netherlands, Zimbabwe (supported by Denmark), Brazil (supported by France), Senegal (supported by France), Poland (supported by USA). Negotiations are under way with several governments concerning support to additional developing countries.

The Danish component of the project is being carried out by the Energy Systems Group at Risø. This comprises both a country study for Denmark, supported by the Danish Ministry of Energy, and a collaborative effort with the Ministry of Energy and Water Resources and Development in Zimbabwe. The latter study is financed by Danida.

The various participants in the project met together for the first time at a workshop held at Risø on 4 and 5 December 1991. Here the status of work in the countries was discussed and overview presentations of key areas were given by invited speakers. Much of the workshop was taken up by a discussion of the methods and assumptions to be used in the country studies.

A status report will be prepared midway through the project when the reviews of existing national studies have been completed. The project is expected to be completed at the end of 1992 with the publication of a final report describing the country studies and a general methodological framework for future studies.

5.4 Global Environment Facility (GEF)

The Global Environment Facility (GEF) is a three-year pilot programme established in November 1990 to support activities related to international environmental management and transfer of environmentally benign technologies. Financial support in the form of highly concessional loans and grants is given to developing countries to address specific challenges to the environment in four major programme areas: pollution of international waters, loss of biodiversity, global warming and ozone depletion.

As of 30 September 1991, total GEF commitments have amounted to SDR 984 million (US$ 1,38 billion). Belgium, Canada, New Zealand and a number of developing countries have also indicated their intention to participate. This would bring total commitments to about SDR 1 billion for the entire three-year period (July 1991 through June 1994).

The World Bank, UNDP and UNEP cooperate in the implementation of GEF, and each institution is responsible for specific tasks which relate to its particular expertise. The UNEP provides scientific and technological guidance in identifying and selecting projects and coordinates research and data collection activities. A Scientific and Technical Advisory Panel (STAP) composed of experts from industrialised and developing countries has been convened by UNEP to give advice on broad scientific and technical issues as well as to develop a set of scientific and technical criteria and priorities for each of the four programme areas to guide the selection of GEF projects.

The Centre's role in GEF has been to review and evaluate proposed projects for GEF funding under the Global Warming/Energy programme. The work is being done on an ad hoc basis, consistent with the Centre's mandate of providing scientific and technical support to UNEP. About fifteen global warming project proposals have been referred to the Centre for evaluation so far. In addition, the Centre has established a database of projects submitted to the GEF to enable it to keep track of the status of projects and to ensure that the technical and scientific design of projects are consistent with the criteria and priorities set by STAP.

5.5 UN Solar Energy Group on Environment and Development

Centre staff has been involved in a number of international conferences and committees in many cases also as designated UNEP representative. Perhaps the most significant activity here has been the participation in the work of the United Nations Solar Energy Group on Environment and Development (UNSEGED).

The UNSEGED was established late 1990 by the Director-General for Development and International Economic Cooperation in the UN. Its mandate was to prepare a comprehensive and analytical study on new and renewable sources of energy with a view to provide a significant contribution to the 1992 United Nations Conference on Environment and Development (UNCED). The UN group comprises a total of 30 individual experts and representatives from various UN organisations.

The group met four times in 1991 and the Centre was co-rapporteur on the final chapter setting up an agenda for Renewable Energy Sources in the 1990s and beyond. The report of the group has now been finalized and will be presented as a formal UN document to the UNCED in June 1992.

Among the conclusions and recommendations of the report some of the more important are:

* Establishment of national time-bound targets for the contributions of the different renewable energy sources to the energy supply.

* Introduction of regulatory and fiscal legislation to ensure that all costs and benefits, including social and environmental, are included in economic comparisons for public and private energy sector investments.

* Establishment of a strong international institutional arrangement to coordinate the proposed efforts, preferably in the form of an International Renewable Energy Agency.

Many of the conclusions and recommendations are expected to be discussed at the UNCED and form part of the basis for decisions in the areas of energy and protection of the atmosphere.

5.6 Energy-Environment Implications of Urban Transport in India

Urbanisation generally leads to a greater use of motorised transport and this is no less true in cities in developing countries. The increasing size of cities and the haphazard growth of work places and residential areas leads to longer and increasing numbers of trips per person. This in turn raises the emission levels of carbon monoxide, hydrocarbons, nitrogen oxides, sulphur dioxide, lead and particulates. Due to insuffcent emphasis given to public modes of transport, the private vehicle population has grown dramatically in many developing country cities, with consequent problems of congestion. Very little work has been done so far to assess the environmental implications of energy use in the cities of the developing world, particularly in the transport sector. There can be many reasons for this including the unavailability of suitable data on the emissions of vehicles.

The Environmental Database (EDB) described in section 5.1 has recently been extended to include data on emissions from road traffic in Indian cities. The work is closely tied to ongoing work at the Tata Energy Research Institute (TERI), New Delhi, India on an urban transportation database, and to the development of EDB at the Centre.

A simple model of the road transport sector in the city of Delhi was developed using the LEAP energy planning model with appropriate emission factors in EDB. Data for the growth of vehicle population, occupancy ratios, modal split, vehicle efficiencies and utilization pattern were used to estimate the energy demand in the road transport sector of Delhi. Emission factors were expressed in terms of quantity of pollutant emitted per unit fuel consumption, according to speed and type of vehicle. By linking these emission factors with the appropriate energy consumption values, the total emissions of a number of pollutants could be calculated.

Two scenarios were constructed within the LEAP framework: one in which current trends of the vehicular population are extrapolated and the other in which the modal splits of motorized transport are varied, with a larger shift towards public modes like bus. For both scenarios, energy demand and the pollution loading of CO, HC, Pb, NO_x, SO_2, and particulates were estimated for the years 1990 (base year), 1995, 2000, 2005 and 2010.

The preliminary results obtained from the scenario calculations show how the environmental effects of shifting toward public modes of transport can be quantified. In particular the tool provides a way of assessing systematically the effect of varying the factors which contribute to urban pollution.

This activity thus provides a useful tool for analysing the situation in Indian urban areas as well as expanding the scope of EDB for use in the transport sector of other developing countries. Specific data on vehicle population, modal split, transport demand, etc. will be necessary in any other application. The structuring of the problem in the Indian case, however, should lend itself to other developing country situations.

6 Conferences, Publications, Lectures and Committees

6.1 Conferences

In 1991 the department was strongly involved in organising the 3rd International Conference on a System Analysis Approach to Environment, Energy, and Natural Resource Management in the Baltic Region.The conference was organised jointly with the Danish Energy Agency,Danish Environmental Research Institute, Roskilde University Centre, and the Technical University of Denmark. It was sponsored by the Nordic Council of Ministers, the Interministerial Committee for Central and Eastern Europe, and the Danish Social Science Research Council.

This was the third in a series of interdisciplinary conferences aimed at further developing the scientific basis for a holistic analysis of the environmental problems in the Baltic Region. The first was held in Gdansk, September 1988, and the second in Leningrad, November 1989.

The Conference took place 7 - 10 May 1991 in »Eigtveds Pakhus« in Copenhagen and attracted wide interest. The 115 participants represented all countries around the Baltic Sea, and comprised scientists, planners and economists from universities, research institutes and private companies. Altogether 72 papers were presented, of which 44 were delivered orally and the rest as posters.

The focus was on the Baltic Region, which is a limited geographical area with varying but comparable climate, vegetation and cultural background. The Baltic Sea and surrounding terrestrial areas constitute a more or less coherent ecological system, and many of the actual environmental problems in the Baltic Region call for solutions involving several countries, and thus for an extended international cooperation.

A simple structure was chosen for the conference, with strategies for environmental management interrelating the different parts of the environmental problems as activities and sources and pollution,dispersion and impacts.

After an opening session the three main sessions in the conference treated these subjects notet above. The first session dealt with methods for identification, quantification and regulation of emissions from energy production and consumption, industrial processes, forestry, agriculture and other human activities. The second session dealt with dispersion, transformation, deposition and effects of pollutants in relation to the critical loads in the Baltic Region. The third session dealt with analyses of those aspects of socioeconomic development that are significant for environmental problems, and evaluation of the impact of various technical, economical and legislative interventions in relation to environmental strategies.

Emphasis was put on human activities giving rise to environmental problems. Not only energy production, industry, agriculture and other primary activities but also the subsequent consumption and waste disposal were treated. In the concluding session the coordinators presented their views and conclusions of their individual sessions together with presentations concerning funding possibilities for joint projects. Finally, it was announced that the next conference in the series will take place in Tallinn, Estonia May 24-27,1993.

The conference proceedings containing the full text of the majority of the oral presentations and abstracts of posters presented at the conference were published in December 1991 as a book in the Nord-series.

6.2 Publications

1. **Amann, M., and Sørensen, L.** The RAINS Energy and Sulfur Emission Database, Status 1991. Working Paper WP-91-xx, IIASA, A- 2361 Laxenburg, Austria.

2. **Amann, M., Hordijk, L., Klaassen, G., Schopp, W.** and **Sørensen,** L. Economic Restructuring in Eastern Europe and Acid Rain Abatement Strategies. Working Paper WP-91-026. IIASA, A-2361 Laxenburg, Austria.

3. **Andersen, V.; Uuspää, P.,** ISEM: Europe's ESPRIT support for emergency management. Nucl. Europe Worldscan (1991) (no.11/12) p. 20.

4. **Andersen, V.;** IT Support for Emergency Management - ISEM; in Working Material, Practical Experience with Expert System Applications in Nuclear Safety, Report of a Technical Committee Meeting/Workshop organized by the International Atomic Energy Agency, held in Moscow, 1-5 October 1990, IAEA-J4-TC-660.2; IAEA Vienna, Austria, 1991.

5. **Bannon, L.; Robinson, M.; Schmidt, K. (eds.),** Proceedings of the 2. European conference on computer-supported cooperative work. ECSCW '91, Amsterdam, 24-27 Sep 1991. (Kluwer Academic Publishers, Dordrecht, 1991) 349 p.

6. **Brehmer, B.; Leplat, J.; Rasmussen, J.,** Use of simulation in the study of complex decision making. I: Distributed decision making. Cognitive models for cooperative work. Ramussen, J.; Brehmer, B.; Leplat, J. (eds.), (John Wiley and Sons, Chichester, 1991) (New technologies and work) p. 373-386.

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8. **Christensen, J.M.; Mackenzie, G.A.,** Policies for sustainable energy development. Analysis from a UNEP perspective. I: Global collaboration on a sustainable energy development. Conference proceedings. Global collaboration on a sustainable energy development, Snekkersten, 25-28 Apr 1991. Meyer, N.I.; Nielsen, P.S. (eds.), (Physics Laboratory 3. Technical University of Denmark, Lyngby, 1991) p. 211-223.

9. **Christensen, P.; Kongsø, H.E.,** The use of on-line reliability analysis for maintenance planning. I: Operational reliability and systematic maintenance. Holmberg, K.; Folkeson, A. (eds.), (Elsevier Applied Science, London, 1991) p. 271-282.

10. **Christensen, P.; Smith-Hansen,** L.; **Heino, P.; Fassera, G.; Poucet, A.,** The use of knowledge bases in advanced computer aided safety analysis. I: Reliability '91. International conference on reliability techniques and their application, London, 10-12 Jun 1991. Matthews, R.H. (ed.), (Elsevier, London, 1991) p. 589-599.

11. **Christensen, P.; Smith-Hansen, L.,** Use of generic and plant specific knowledge in STARS. I: STARS project conference, Tampere, 5-6 June 1991. (VTT, Tampere, 1991) Section 9. 7 p.

12. **Rambøll & Hannemann A/S;** RUC Institute for Environment, Technology and Social Studies; Risø National Laboratory; The County of Storstrøm, Energy Planning in Gliwice, Poland. Preliminary project. Main report July 1991. (Commission of the European Communities DG XVII, The Danish Interministerial Committee for Central and Eastern Europe. (The IMØ Project Fund), 1991) 128 p.

13. **Fenger, J.; Fenhann, J.; Kilde, N.,** Danish budget for greenhouse gases. (Nordic Council of Ministers, Copenhagen, 1990) (NORD, 97) 116 p.

14. **Fenger, J.; Fenhann, J.; Kilde, N.A.,** Danish budget for greenhouse gases. I: Environment, energy and natural resources management in the Baltic Region. 3. International conference on system analysis, Copenhagen, 7-10 May 1991. Fenger, J.; Halsnæs, K.; Larsen, H.; Schroll, H.; Vidal, V. (eds.), (Nordic Council of Ministers, Copenhagen, 1991) (NORD, 48) p. 125-134.

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16. **Fenhann, J.** (ed.), Energy and environment in Estonia, Latvia and Lithuania. Risø-M-2943 (1991) 87 p.

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Morthorst, P.E. Samfundsøkonomiske analyser af biogasfúllesanlúg (The economics of joint biogas plants). Seminar on the Danish Biogas Action Programme, 1991.

Morthorst, P.E. The Danish Energy 2000 - plan with special focus on CO_2-reductions. Seminar on UNEP National Greenhouse costs study, Risø 1991.

Ott, S., Smith-Hansen, L. Udslip og spredning af gasser (Release and dispersion of gasses). University of Lund, Sweden, 25-26 November 1991.

Paulsen, J.L. Practical examples of Displays for technical systems. Georgia Institute of Technology, Atlanta, USA, 12-13 December 1991.

Pejtersen, A.M. The Book House for Fiction Retrieval. Workshop on Libraries for the End Users. NORDBOOK, Åbo, Finland, 12-16 August 1991.

Pejtersen, A.M. Information Retrieval with Multimedia Access. Seminar arranged by Dublin Publin Library System, Dublin, Ireland, 11 July 1991.

Pejtersen, A.M. Design of a Cognitive System for Information Retrieval in Libraries by means of Icons. The Informatics 11 Conference on Information and Knowledge Structures. Arranged by ASLIB, The Association for Information Management. England, York, 20-23 March 1991.

Pejtersen, A.M. Information Retrieval with Multimedia Access. Seminar arranged by Napoli National Libraries, Napoli, Italien, 19 March, 28 August 1991.

Pejtersen, A.M. Design of a Cognitive System for Information Retrieval in Liraries. University of Liverpool, England, 19 March 1991.

Pejtersen, A.M. The Book House System For Intelligent Retrieval in Work Stations. Third Scandinavian Conference on Artificial Intelligence arranged by Roskilde University, Risø, Denmark, 21-24 May 1991.

Pejtersen, A.M. Methods for design and evaluati on of the Book House system for libraries. ERFA meeting arranged by Danish Technological Institute, Copenhagen, 15 March 1991.

Pejtersen, A.M. Ecological Interfaces for Library Systems. HITACHI Human Computer Interaction Research Division, Tokai Mar, Japan, 28 November 1991.

Pejtersen, A.M. Ecological Interfaces for Advanced Information Systems. Japanese Atomic Energy Research Institute, Tokai, Japan, 29 November 1991.

Pejtersen, A.M. New Methods for Design of Personalized Information Systems for Retrieval in Integrated Work Stations. Friend 21 meeting arranged by the Institute for Design of Personalized Information Environm ents, Tokyo, Japan, 2 December 1991.

Pejtersen, A.M. Information Retrieval in School Libraries by means of the Book House sys tem. The Danish University for Educational Studies, Copenhagen, 11 June 1991.

Pejtersen, A.M. Information Retrieval and Decision Making with an Icon based Interface. PRIMA Seminar arranged by Copenhagen Business School, Copenhagen, 18 April 1991.

Pejtersen, A.M. Ecological Interfaces and Cognitive Design Principles illustrated by the Book House. Seminar on Interfaces of the 9 0ties. Computer Resources International, Copenhagen, 26 September 1991.

Pejtersen, A.M. Cognitive System design for Interactive Information Retrieval in Libraries. Fourth International Conference on Human Computer Interaction. University of Stuttgart, G ermany, 2-6 September 1991.

Petersen, K.E. Risikoanalyse - Eksempel påå branchеløsning i træimprægneringsindustrien (Risk analysis - examples of common solution for the wood treatment industry). Danish Plastics Industry, 29 January 1991.

Petersen, K.E. Menneskelige betjenings- og designfejl (Human errors in operation and design). Dansk Ingeniørforening. Society for Risk Assessment, 12 February 1991.

Rasmussen, B. Uønskede kemiske reaktioner (Unwanted chemical reactions). The Technical University of Denmark. 19 April 1991.

Rasmussen, B. Risikoanalyse (Risk analysis). Naturfagslærerforeningen, Copenhagen, 5 October 1991.

Rasmussen, B. Metoder til risikoanalyse (Risk analysis methods). Directorate of National Labour Inspection. 20 November 1991.

Schmidt, K. Models in CSCW, Plenary panel, COSCIS '91, Helsinki, 27-29 August 1991.

Schmidt, K. Modelling Cooperative Work for CSCW Systems, Plenary panel, International Workshop on CSCW, Berlin, April 9-11, 1991.

Sørensen, L. Critical Viewpoints on the Danish Water Action Plan. »Nordisk Forskarkurs« on Problem Structuring Methods, Reykjavik, 2-8 June 1991.

6.4 Committees

Danish:

1. Research committee, Energy and Society (Min. of Energy).
   Hans Larsen.
2. Inter-ministerial committee on energy policy in the EC (Min. of Energy).
   Niels J. Thomsen.
3. Steering committee, Danish Society for Risk Assessment.
   Birgitte Rasmussen.
4. Environmental Appeal Board.
   Dan S. Nielsen.
5. Committee on standards for risk analysis (Danish Society of Chemical, Civil, Electrical and Mechanical Engineers).
   Kurt E. Petersen.
6. Board of Governers, Energy Centre Denmark.
   Hans Larsen.
7. Electricity forecasting group (Min. of Energy).
   Poul E. Morthorst.
8. Danish Council for Renewable Energy.
   Poul E. Morthorst.
9. Data group concerning energy consumption in the transport sector(Danish Energy Agency).
   Jørgen Fenhann.
10. Board of management, Center for Cognitive Informatics.
    Hans Larsen.
11. Committee on Research and Development (Federation of Danish Trade Unions).
    Kjeld Schmidt.

International:

1. Ad hoc expert group of the CAN-JOULE for energy and environmental models (C.E.C.).
   Hans Larsen.
2. CGC-5 Nuclear fission energy, safety (C.E.C.).
   Hans Larsen.
3. Steering committee, European Safety and Reliability Association (C.E.C.).
   Kurt E. Petersen.
4. Editoral board, Journal of Loss Prevention in the Process Industries.
   Birgitte Rasmussen.
5. Editoral board, Nuclear Instruments and Methods, Section A.
   Palle Christensen.
6. Committee for European Standards on Nuclear Electronics (C.E.C.).
   Palle Christensen.

7. International Progamme Committee for REL-91, Reliability Conference, June 1991, UK.
   Kurt E. Petersen.
8. Steering committee, SHARE (Safety Management and Hazard Assessment Research Cooperation in Europe, C.E.C.).
   Kurt E. Petersen.
9. United Nations Solar Energy Group for Environment and Development.
   John M. Christensen.
10. Progamme Committee for 3rd International Conference on a Systems Analysis Approach to: Environment, Energy and Natural Resource Management in the Baltic Region, May 1991, Denmark.
    Hans Larsen (Chairman).
11. Organising Committee for 3rd International Conference on a Systems Analysis Approach to: Environment, Energy and Natural Resource Management in the Baltic Region, May 1991, Denmark.
    Jøgen Fenhann, Kirsten Halsnæs.
12. Management and Policy Committee for UNEP Collaborating Centre on Energy and Environment.
    Hans Larsen (Chairman), John M. Christensen.
13. Halden Progamme Group (OECD).
    Hans Larsen.
14. Progamme Committee for the International Conference on Global Collaboration on a Sustainable Energy Development, April 1991, Denmark.
    John M. Christensen.
15. Editoral Board, Reliability Engineering & System Safety.
    Kurt E. Petersen.
16. TELEMAN User Group (C.E.C.).
    Kurt E. Petersen.
17. Programme Committee for the European Safety and Reliability Conference '92, June 1992, Denmark.
    Hans Larsen (Chairman).
18. Organising Committee for the European Safety and Reliability Conference '92, June 1992, Denmark.
    Kurt E. Petersen (Chairman).
19. Steering Committee, Society of Reliability Engineers Scandinavia.
    Kurt E. Petersen.
20. Programme Committee for ESREL-93 Reliability Conference, May 1993, Germany.
    Kurt E. Petersen.
21. Editoral Board, An International Journal of Computer Supported Cooperative Work.
    Kjeld Schmidt.
22. Management Committee of COST Action 14 »CoTech«.
    Kjeld Schmidt.
23. Programme Committee for Second European Conference on Computer Supported Cooperative Work, September 1991, The Netherlands.
    Kjeld Schmidt.
24. Expert Group on Comparative Environmental and Health Effects of Different Energy Systems for Electricity Generation, for Senior Expert Symposium on Electrcity and the Environment,IEA, UNEP a.o., Helsinki, May 1991.
    John Christensen.

7 STAFF

Hans Larsen, M.Sc. (Elec. Eng.), Ph.D. The Technical University of Denmark 1972. From 1973 to 1976 at Dragon project at AEE Winfrith, U.K. Risø from 1976. Energy Technology Department 1976-80, working with systems reliability. Head of Energy Systems Group 1980-84. Head of Systems Analysis Department from 1985.

Leif Hansson, M.Sc. (Elec. Eng.). Risø from 1961. Head of Computer Group/Computer Installation 1963-86, Deputy Head of Department of Information Technology 1986-90. Systems Analysis Department from March 1990 until July 1991.

Cognitive Systems Group

Leif Løvborg, M.Sc. (Elec.Eng.) Risø from 1962. Radioisotope techniques (1962-66), nuclear geophysics and mineral exploration (1967-86). Group Leader (Electronics Dept.) 1965-86, Lead Scientist in OECD/IAEA action to improve uranium exploration methods 1979-85. Cognitive engineering research from 1986. Acting Leader of Cognitive Systems Group from February 1990. Main research activity: Experimental investigation of human co gnitive behaviour in simulated »microworlds«.

Henning Boje Andersen, M.A. (Philos.). Copenhagen University and Oxford University (logic, philosophy of language) 1976-79. Medical Faculty, Copenhagen University and Roskilde University, (philosophy of science) 1980-83. Risø from 1984, Cognitive Systems Group from February 1990. Main activities: Human-computer interaction, systems support of emergency management and multi-user training, modelling temporal reasoning.

Verner Andersen, M.Sc. (Elec.Eng.), Ph.D. Risø from 1966. Nuclear physics (1966-76), plasma physics (1976-86). Leader of programme on plasma-physics technology 1983-86. Information technology from 1986. Coordinator of the joint Nordic programme for nuclear emergency management (1986-90). Manager of CEC Esprit Action 2322, »IT Support for Emergency Management« (ISEM). Cognitive Systems Group from February 1990 (as Project Leader). Main activity: Project management, systems development.

Gunnar Hovde, M.Sc. (Psychol.). Lecturer in perceptionps ychology and socil psychology at Aarhus University 1975-85. Risø from 1985. Man-machine interaction, field studies within manufacture and health care. Cognitive Systems Group from February 1990 until May 1991.

Michael May, M.Sc. (Psychology & Cultural Sociology, 1985), Ph.D. (under evaluation, spring 1992). Risø from 1991. Psychological Laboratory, University of Copenhagen (1987-1990), Center for Cognitive Science, University of Roskilde (1990-1991). Main research interests: cognitive semantics, logical semantics, semiotics & AI. Main activities: Taxonomy of graphical objects in HCI, Semantic analysis of computer interfaces, Semiotic theory of multimedia design.

Finn R. Nielsen, M.Sc. (Appl. Math. & Phys.). Technical College of Copenhagen 1968-74. Risø from 1974. Computer programming for models and graphical interfaces within man-machine studies and operator support facilities, for compilers and data bases in minicomputer environments, for simulation of power plants for diagnosis and control (1974-1989). Cognitive Systems Group from February 1990. Main activities: Cognitive simulation, implementation of design concepts.

Annelise Mark Pejtersen, M.A. (Sci. of Lit.). University of Copenhagen 1971-73, Associate Professor at the Royal School of Librarianship 1971-82, Acting Professor 1983-85. Visiting Senior Research Scientist at Georgia Institute of Technology 1982-83. Risø from 1986 (as Project Leader). On leave as manager of the Labour Unions' Centre for Informatics 1989-90. Cognitive Systems Group from February 1990. Main activities: Project management, user modelling, ecological design concepts, multimedia interfaces, taxonomy of work domains.

Kjeld Schmidt, M.Sc. (Sociol.), Senior Scientist. Roskilde University 1972-85, Dansk Datamatik Center 1985-88, Labour Unions' Centre for Informatics 1989-90. Cognitive Systems Group from March 1990. Main activities: Theory and methodology for analysis of cooperative work in complex settings, Computer-Supported Cooperative Work, taxonomy of work domains.

Steen Weber, M.Sc. (Elec.Eng.), Ph.D. Risø from 1972. Computer codes for nuclear fuel management (1974-75). Risk Analysis Group (Dept. of Energy Technology) 1975-84 , Acting Group Leader 1982-83. Core simulator project, risk analysis of off-shore platforms. Development and use of codes for fuel management in collaboration with Danish utilities (1984-87). Leader of project on knowledge-based system for control of heat distribution (1988-89). Cognitive Systems Group from February 1990. Main activity: Advanced interfaces and data bases for information retrieval systems.

Scientific Coordinator

Jens Rasmussen, Research Council Professor, M.Sc. (Elec.Eng.). Risø from 1956. Control engineering (1956-62), Head of Electronics Dept. 1962-86. Member of Danish Academy of Technical Sciences (1962). Visiting Professor at Center for Man-Machine Systems Research, Department of Industrial Engineering, Georgia Institute of Technology (1982-83). From 1986 Research Council Professor affiliated to Risø and the Technical University of Denmark. Coordinator of CEC ESPRIT-2 basic research action 3105, »Models of Human Actions in Work Context« (MOHAWC). Coordinator of the research activities in the Cognitive Systems Group from February 1990. By the end of 1991 Jens Rasmussen retired from his post as a Research Council Professor at Risø and the Technical University of Denmark. Jens Rasmussen will continue his affiliation with the Group as a consultant.

Energy Systems Group

Niels Juhl Thomsen, M.Econ. Danish Ministry of Education 1978-79, Danish Ministry of Housing and Building 1979-81, Danish Ministry of Energy 1981-89. Joined Risø as Head of Energy Systems Group in May 1989. Main activities: General energy planning and economics of renewable energy.

Frits Møller Andersen, M.Econ., Senior Scientist. Specialized in econometrics and macro-economic modelling. Research assistant Århus University 1978. Assistant planner in local government 1979. Risø from 1980. Main activities: The macro-sectoral model HERMES for Denmark and a technical-economic model for the Danish industrial energy consumption.

Peter Skjerk Christensen, M.Sc. (Elec. Eng.). Risø from 1958. Nuclear research and education (1958-69), reactor engineering and thermohydraulics including simulation models (1969-76), Energy Systems Group from 1977. Main activities: Energy systems modelling. From November 1990 stationed in Cape Verde Islands as energy advisor to the government.

Jørgen Fenhann, M.Sc. (Physics with mathematics and chemistry). Niels Bohr Institute 1977. Risø from 1978. Main activities: Development of energy planning models, economics of new and renewable energy technologies, calculation of emission from energy system, and energy-environmental planning for Eastern European countries.

Poul Erik Grohnheit, M.Econ., Senior Scientist. Danish Building Research Institute 1969-71, town planning consultant 1971-72 and 1979-80, budgetting and economic planning in local government 1973-79. Risø from 1980. Main activities: Energy system and environmental modelling, and economics of power plants.

Kirsten Halsnæs, M.Econ., Senior Scientist. Danish Ministry of Housing and Building 1983-87. Risø from April 1987. Main activities: Nordic collaboration on integrated energy environmental planning, integrated models, environmental economics, energy and environment in Eastern European countries.

Lotte Schleisner Ibsen, M.Sc. (Mech. Eng.). Risø from 1984 in Research Section of the Engineering Department working on aquifer thermal energy storage. Joined Energy Systems Group in 1989. Main activity: Assessment of energy technologies.

Niels A. Kilde, M.Sc. (Chem. Eng.). The Danish Steelworks Ltd. 1962-81. Research and quality control (1962), planning and administration (1967), casting department manager (1972), development and energy manager (1977). Risø from 1981. Member of the steering group for R&D in industrial processes of the Ministry of Energy.

Main activities: Energy use in industry and transport, emissions inventory.

Helge V. Larsen, M.Sc. (Elec. Eng.), Ph.D. Technical University of Denmark 1974. Storno A/S from 1975. Risø from 1976. Department of Reactor Technology 1976-77. Energy Systems Group from 1977. Main activities: CHP production, modelling of energy systems, economic models for the oil and gas sector, development of planning models for wind energy.

Poul Erik Morthorst, M.Econ., Senior Scientist. Economist specialized in econometrics and macro-economics. Risø from 1978. Head of Energy Systems Group 1985-89. Main activities: General energy planning and modelling with emphasis on forecasting electricity demand forecasting, economics of renewable energy technologies, especially wind turbines.

Lars Henrik Nielsen, M.Sc. (Phys., Math.). Risø from 1981. Main activities: Probabilistic methods and model development, technical-economic modelling, and assessment of energy technologies, especially renewable energy, emissions calculations.

Peter Stephensen, M.Econ. Ph.D. student at Institute of Economics, University of Copenhagen 1989-1991. Specialized in theoretical economics. Risø from 1991. Main activities: Environmental economics and demand-side management.

Risk Analysis Group

Kurt Erling Petersen, M.Sc., Ph.D. Risø from 1977. Department of Energy Technology 1977-84. Risk Analysis Group from 1984. Main activities: Development of computer codes for reliability analysis, development of tools for operation and maintenance, and treatment of re liability data. Head of Risk Analysis Group from 1990. Deputy head of Systems Analysis Department.

Palle Christensen, M.Sc. (Elec. Eng.). Risø from 1962. Elec tronics De partment 1962-86 working on nuclear instrumentation, research instrumentation and reliability projects. Department of Information Technology 1986-88 working on knowledge-based computing. Secretary of Risø's patent council 1973-88. Risk Analysis Group from 1988. Main activity: Development of computer codes for reliability, and safety analysis.

Carsten D. Grønberg, M.Sc. (Elec. Eng.). Risø from 1967. Electronics Department 1967-78. Safety Department 1978-83. Risk Analysis Group from 1984. Main activities: Human factors, emergency planning, risk communication, risk management.

Hans E. Kongsø, M.Sc. (Mech. Eng.). Risø from 1957. Research reactor DR 2 1957-63, Department of Energy Technology 1963-84. Risk Analysis Group from 1984. Main activities: Computer codes for reliability and consequence assessment, and reliability and risk assessment of nuclear and industrial plants.

Lauridsen, Kurt, M.Sc. (Electrical engineering), Ph.D. (Nuclear engineering). Risø since 1974. Department of Energy Technology 1974-87, working with nuclear safety and industrial risk analysis. Department of Informatics 1987-90. Risk Analysis Group from March 1990. Main activities: Reliability analysis, risk management.

Dan S. Nielsen, M.Sc. (Elec.Eng.). Risø from 1962. Electronics Department 1962-84. Risk Analysis Group from 1984. Main activities: Risk analysis of individual plants, physical modelling for consequence assessments.

Søren Ott, Ph.D. (Turbulence theory), Risø from 1985. Main activities: Models and computer codes for consequence assessment; dense gas dispersion and flame experiments.

Jette Lundtang Paulsen, M.Sc. Mechanical engineering, DTH 1972. From 1972-80: Research reactor DR3. From 1980-86: Uranium Extraction project. From 1986-90: Department of Informatics. From 1990 Department of Systems Analysis. Main activities: Maintenance planning, software development, interface systems.

Birgitte Rasmussen, M.Sc. (Chem. Eng.), Ph.D. The Technical University of Denmark from 1981-84. Risø from 1984. Main activities: Risk assessment of industrial activities, risk management, risk communication.

Lene Smith-Hansen, M.Sc. (Chemistry). Risø from 1986. Main activities: Risk assessment of chemical plants, toxic effects from releases, and quantitative assessment of toxic chemical substances from combustion.

UNEP Collaborating Centre on Energy and Environment

John Møbjerg Christensen, M.Sc. (Eng.) Ph.D. Danish National Agency of Technology 1980-83, R&D initiation and administration, Oilconsult, Consulting Engineers and Planners 1983-84, R&D Energy Planning, NRSE projects. Risø from 1984. Energy Systems Group 1984-88. Programme Officer, Energy Unit, United Nations Environment Programme 1988-90. Head of UNEP Collaborating Centre on Energy and Environment from October 1990. Main activities: energy-environment planning in developing countries, project initiation, UN contacts and coordination.

Camilo Jose C. Lim, Jr., M.A. (Dev. Econ.) Risø from June 1991. International experience in energy policy, planning and research. Previous posts as economist with the Philippine government and researcher at the Asian Institute of Technology (Thailand). Main activities at the Centre include energy and environment planning, policy research, and project evaluation; model and database development and use.

Gordon A. Mackenzie, B.Sc. Ph.D. (Physics). Guest researcher at Risø 1974-78. Lecturer at Edinburgh University 1978-79. Energy Systems Group from 1980. 1984 to 1987 Energy Adviser/ Deputy Director at Department of Energy, Zambia. From February 1988 until February 1990 leader of Environmental Modelling Group. From October 1990 with UNEP Collaborating Centre on Energy and Environment as senior energy planner. Main activities: integrated energy/environmental models, energy and environment in developing countries, environmental database.

Arturo Villavicencio, M.Sc. (Math.) National Energy Institute (Ecuador) 1979-85. Energy Planning Consultant for the Latin American Energy Organisation, CEC and World Bank 1985-88. Energy Adviser at OLADE 1988-90. From May 1991 with UNEP Collaborating Centre on Energy and Environment. Main activities: Energy/environmental models, integrated energy-environment planning in Latin America.

Postgraduate Students

John Paulin Hansen, M.Sc. (Psychol). Major subject: Visual perception, recording of eye movements, evaluation of interfaces, cognitive modelling. Ph.D. student at Risø from 1988. Subject: Perception and cognition in complex work situations.

Lisbeth Grænge Hansen, M.Econ. Major suject: Environmental Regulation in an International Perspective. Ph.D. student at Risø from April 1991. Subject: Guidelines in International Conventions concerning the Environment - Greenhousegases and climate-agreements.

Lis Ketscher, M.Sc. (Psychol.). Danish Royal School of Education 1982-1985. Risø 1987-1988 as scientific assistant in a project on computer-assisted knowledge exploration, supported by the Danish Research Council for the Humanities. Main activities: Knowledge representation, knowledge structure, development of methods for probing mental models; problem solving and decision making. Ph.D. student at Risø from 1989. Subject: Knowledge acquisition and knowledge structures in computer-simulated task performance.

Søren Nors Nielsen, M.Sc. (Biol.), Major subject: Aquatic ecology and dynamical modelling of eutrophication processes. Ph.D. Study at Risø from 1989 on: Structural dynamical modelling of aquatic ecosystems and application of exergy as optimizing function until August 1991.

Schnipper, Anette, M.Sc. (Pharm.). The Royal Danish School of Pharmacy 1989-90. Ph.D. Student at Risø from 1990. Subject: Toxic Products in Smoke from Chemical Fires.

Sørensen, Lene, M.Sc. (Eng.) Major subject: Strategies for Controlling Danish Waste Water Plants. Ph.D. student at Risø from April 1990. Subject: Integrated Environmental Models and Uncertainty.

Guest Researchers

Ranjan K. Bose, B.Sc. (Mathematics) M.Sc. (Statistics) Ph.D. (Energy-Environment Planning). Research Associate, Energy Policy Division, Tata Energy Research Institute (TERI), New Delhi, India, 1982-91. Fellow, Energy Policy Division, TERI, from July 1991. Guest researcher with UNEP Collaborating Centre 1 October to 31 December 1991 working on energy-environment implications of urban transport.

Tibor Csürök, M.Sc. (Mech.Eng.), Technical University of Budapest, Hungary. 1 September - 31 October 1991. Reliability of thermal power plants and their equipment.

Jan Scherfig, Ph.D.,Civil Eng. Professor of Environmental Engineering. University of California Irvine, 1969. University of California Scandinavian Study Center 1989-91. Main activities: Water reclamation and rinse, industrial waste treatment; entrophications, biomass control; economic analysis of waste treatment systems.

Kim Vicente, PhD., Georgia Institute of Technology, 20 June - 10 Sept. Interface design principles, experimental evaluation of interfaces.

Programmer

Søren Præstegaard, datanom. Regnecentralen 1973-79. Risø from 1979. Datanom with special subject: Optimization completed 1985 at EDP-school, Copenhagen. Working on simulation models, graphics, and general user support.

Secretaries

Maria M. Andreasen
Gytha Egelund
Jette Larsen
Annette Dahl Poulsen
Irma Strandvad

Research Technician

Erling Johannsen

Temporary Staff

Jeffrey Mark James, BSc. (Psychol. and Elec.Eng.), 1 June - 31 August. Programming assistance with the BOOKHOUSE and the ISEM project.

Bjarne Kaavé, M.Sc. (Eng.), 17 June - 31 Dec. User interview and planning for making improvements of Risø's de-centralized administrative data handling system.

Steffen Villumsen (information consultant), from 4 Nov. Software testing, user documentation, and evaluation of user performance under the BOOKHOUSE project.

Liam Bannon, PhD., Copenhagen Business School, 20 Nov. - 31 Dec. Consultancy on the foundations of Computer Supported Cooperative Work.

Dan Shapiro, Director of Centre for Research in CSCW at Lancaster University, 2-6 Dec. Consultancy on sociological and ethnografic approaches to Computer Supported Cooperative Work.

Henrik Sørensen, M.Sc. (Elec.Eng.) September - December 1991. Specialized in renewable energy. Modelling power systems, in particular hydro power.

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The report describes the work of the Systems Analysis Department at Risø National Laboratory during 1991. The Department is made up of the Cognitive Systems Group, the Risk Analysis group, the Energy Systems Group and the UNEP Collaborating Centre for Energy and Environment. The report includes list of publications, lectures and staff members.

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